THE
GEOLOGICAL MAGAZINE

VOLUME LXII.

No. VIII.—AUGUST, 1925.

ORIGINAL ARTICLES.

Sedgwick Museum Notes.

The Characteristic Assemblages of the Graptolite Zones of the British Isles.

By Gertrude L. Elles, D.Sc., Fellow of Newnham College, Cambridge.

IT has become increasingly evident during the past few years that there are many geologists working on the older Palaeozoic rocks in various parts of the British Isles, to whom a knowledge of the common assemblages of graptolites characteristic of our different British graptolite zones might be useful. In the following lists, therefore, an attempt has been made to put together the facts gleaned from the study of the Graptolite Shales of the British Isles in many widely separated localities. The lists do not claim to be in any way a complete representation of the entire fauna of any zone, but merely an enumeration of those graptolites which in the author's experience are most universally and abundantly represented, so that they are likely to be the forms met with most characteristically in an exposure of any particular horizon. Some co-mingling at the boundaries of the zones must naturally be expected, especially when dealing with a succession of purely shaly deposits, but as a rule even then the *coming in of new forms in abundance* should be taken as an index of the passage to a higher horizon. This fact is one upon which great emphasis should be laid, it is upon this *coming in of new forms*, usually indicative of a more advanced stage in evolution, that the basis of modern zonal stratigraphy is laid; the persistence of old forms tends to vary greatly in different localities with the richness of the previous fauna; when the fauna of the earlier zones was both rich and varied, there are naturally more survivors into the succeeding zones than when the fauna was a poor one.

The actual list of zones here given is much the same as that published in the *Monograph of British Graptolites*, for though there has been a tendency in recent years to re-name some of these zones because of the greater abundance of a certain fossil in a certain locality, there does not really seem to be any justification for such action, which results from focussing too much attention upon the index fossil rather than upon the *assemblage*, which is the determining factor.

BRITISH GRAPTOLITE ZONES.

TREMADOCIAN.
- Zone of *Dictyonema sociale* (or *D. flabelliforme* ?).
- ,, *Bryograptus.*

ARENIGIAN.
- Zone of *Dichograptus.*
- ,, *Didymograptus extensus.*
- ,, ,, *hirundo.*

LLANVIRNIAN.
- Zone of *Didymograptus bifidus.*
- ,, ,, *murchisoni.*

LLANDEILIAN.
- Zone of *Glyptograptus teretiusculus.*
- ,, *Nemagraptus gracilis.*
- ,, *Climacograptus peltifer* and *Mesograptus multidens.*

CARADOCIAN.
- Zone of *Climacograptus wilsoni.*
- ,, *Dicranograptus clingani.*
- ,, *Pleurograptus linearis.*

ASHGILLIAN.
- Zone of *Dicellograptus complanatus* (? pathological).
- ,, ,, *anceps.*

VALENTIAN.

(Lower.)
- Zone of *Glyptograptus persculptus* and *Cephalograptus acuminatus.*
- ,, *Orthograptus vesiculosus*
  - Sub-zone of *Monograptus atavus.*
  - Sub-zone of *Monograptus acinaces.*
- ,, *Monograptus cyphus.*
- ,, ,, *gregarius*
  - Sub-zone of *Monograptus fimbriatus.*
  - Sub-zone of *Monograptus triangulatus.*
  - Sub-zone of *Monograptus argenteus.*
- ,, ,, *convolutus.*

(Upper.)
- Zone of *Monograptus sedgwicki.*
- ,, ,, *turriculatus.*
- ,, ,, *crispus.*
- ,, ,, *griestoniensis.*
- ,, ,, *crenulatus.*

SALOPIAN (Wenlock).
Zone of *Cyrtograptus murchisoni.*
,, *Monograptus riccartonensis.*
,, *Cyrtograptus symmetricus.*
,, ,, *linnarssoni.*
,, ,, *rigidus.*
,, ,, *lundgreni.*

SALOPIAN (Ludlow).
Zone of *Monograptus vulgaris.*
,, ,, *nilssoni.*
,, ,, *scanicus.*
,, ,, *tumescens.*
,, ,, *leintwardinensis.*

TREMADOCIAN-ARENIGIAN ASSEMBLAGES.[1]

5. ZONE OF D. HIRUNDO.
Didymog. hirundo, *D. nitidus, D. nicholsoni, D. gibberulus ; Phyllog. angustifolius,* **P. typus ; Azygog. suecicus ;** *Glyptog. dentatus.*
Entrance of horizontal *Didymograpti* of type of *D. hirundo* and abundance of scandent *Tetragrapti* (*Phyllograpti*).

4. ZONE OF D. EXTENSUS.
Didymog. extensus, *D. nitidus, D. gibberulus,* **D. deflexus ;** *Tetrag. quadribrachiatus,* **T. bigsbyi, T. amii, T. serra ;** *Phyllog. angustifolius ; Glyptog. dentatus.*
Entrance of reclined *Tetragrapti* and horizontal *Didymograpti.*

3. ZONE OF DICHOGRAPTUS.
Dichog. octobrachiatus ; Loganog. logani ; Clonog. flexilis ; *Tetrag. quadribrachiatus,* **T. crucifer, T. headi ; Azygog. lapworthi.**
Entrance of *Loganograptus* and *Dichograptus.*

2. ZONE OF BRYOGRAPTUS.
Bryog. cumbrensis, Br. divergens ; Clonog. tenellus, and var. **callavei.**
Entrance of *Clonograptus.*

1. ZONE OF DICTYONEMA SOCIALE (or DICTYONEMA FLABELLIFORME).

These Tremadocian and Arenigian assemblages call for some comment ; from the work of Cox [2] in N. Wales and others in Shropshire, it seems likely that the *Dictyonema* zone at the base may be divided into two, but it remains for future work to show whether any difference in structure will be found to characterize the graptolites of the two horizons; in this connexion the recent work of Bulman[1] is suggestive. In the succeeding *Bryograptus* zone the evolutional feature of importance is the coming in of horizontally growing graptolites (*Clonograptus*). This genus is still abundant in the *Dichograptus* zone, but except in the lower beds of the zone rarely shows a normal number of stipes; in fact at higher horizons anomalies of this kind are so frequent that these forms have been made the types of a new "genus" (*Anomalograptus*) by Clarke.[2]

---

[1] In these lists species in italics form part of the characteristic assemblage but are not confined to one zone, whilst those in heavier type are practically confined to a zone.

[2] A. H. Cox and A. K. Wells, *Q.J.G.S.*, vol. lxxvi, 1920, p. 257.

The *Dichograptus* zone is characterized by the further development of horizontal forms, and especially by the coming in of *Loganograptus* and *Dichograptus*. Both these forms have a long range, and may even occasionally be found in the zone of *Didymog. extensus*, but these differ in size and are usually mutations in which the full number of stipes is not developed; so, for example, the large *Dichograpti* are more commonly found in the lower part of the *Dichograptus* zone, whilst smaller forms, and the septad, hexad, and pentad mutations are found more particularly in the upper part and in the zone above. Again, the *Tetragrapti*, especially the large *T. crucifer* and *T. headi*, are rare in the lower part of the zone, but are more abundant higher up where *T. quadribrachiatus* makes its appearance usually in fair abundance; such facts may lead eventually to a further subdivision of this zone also, but at present more field evidence is needed in areas at some distance from each other before this can be determined satisfactorily. The same is also the case with the zone of *Didymog. extensus*, which contains an assemblage of graptolites characteristic as a rule of a great thickness of strata. The zone of *Didymog. hirundo*, though containing many fossils characteristic of other horizons, is easily recognized by the coming in of the thick horizontal Didymograptid *D. hirundo*, and the abundance of *Phyllograpti*, though these last are apt to be somewhat local in their distribution.

LLANVIRNIAN-LLANDILIAN ASSEMBLAGES.

Llandilian.

(*Predominance of Leptograptid Type of Cell.*)

10. Zone of Climacog. peltifer and Mesog. multidens.
Climacog. peltifer, *Cl. antiquus, Cl. scharenbergi,* **Cl. bicornis** mut., *Cl. brevis*; *Amplexog. per-excavatus*; **Dicranog. zigzag, D. rectus,** *D. nicholsoni*; *Dicellog. sextans.* **Dicellog. patulosus; Mesog. multidens; Orthog. acutus.**

Entrance of *Dicellograpti* of complex type and large *Orthograpti.*

---

[1] O. M. B. Bulman, Geol. Mag., Vol. LXII, 1925, p. 50.

[2] T. H. Clarke, *Bulletins of American Palaeontology,* vol. x, 1924, No. 41.

9. ZONE OF NEMAGRAPTUS GRACILIS.

Nemag. gracilis and vars.; **Didymog. superstes;** *Glyptog. euglyphus; Orthog. whitfieldi; Climacog. antiquus, Cl. scharenbergi, Cl. brevis,* **Cl. bicornis;** *Cryptog. tricornis; Amplexog. perexcavatus; Dicellog. sextans,* **D. intortus; Hallog. mucronatus; Leptog. validus, L. grandis.**

Entrance of *Nemagrapti* and *Leptograpti* of simple type.

8. ZONE OF GLYPTOGRAPTUS TERETIUSCULUS.

Glyptog. teretiusculus; Mesog. foliaceus; *Climacog. antiquus; Mesog. priscus; Amplexog. perexcavatus; Glossograpti.*

Entrance of *Climacograpti.*

LLANVIRNIAN.

7. ZONE OF DIDYMOGRAPTUS MURCHISONI.

Didymog. murchisoni, D. indentus, D. euodus; *Mesog. priscus;* **Amplexog. coelatus;** *Cryptog. tricornis; Glossograpti.*

6. ZONE OF DIDYMOGRAPTUS BIFIDUS.

Didymog. bifidus, D. artus, D. acutidens, D. stabilis, *D. nicholsoni; Phyllog. typus; Glyptog. dentatus;* **Amplexog. confertus;** *Glossograpti.*

Abundance of tuning-fork *Didymograpti.* Entrance of *Glossograpti.*

The Llanvirnian assemblages are characterized above all by the abundance of *Didymograpti* of the tuning-fork type, and the presence of numerous *Glossograpti* which appear in force for the first time at the base of the zone of *Didymog. bifidus*; since in all probability these are derived directly from *Phyllograpti,* they indicate an advance in evolution along the line of stipe reduction.

The predominant characteristic of all zones of the Llandilian is the presence of the slightly elaborated cell of Leptograptid type in graptolites of very varied outward appearance; thus it is the type characteristic not only of *Leptograptus* itself, but also of *Nemagraptus,* some forms of *Dicellograptus,* and *Glyptograptus.*

The *Glyptog. teretiusculus* horizon is characterized by the abundance of the zone fossil, whilst the zone of *Nemag. gracilis* is easily recognized not only by the abundance of the zone fossil or other *Nemagrapti,* for these are apt to be abundant in bands only, but also by the occurrence of *Dicellog. sextans, Hallog. mucronatus,* and *Orthog. whitfieldi,* which are distinctive, and distributed throughout.

In the zone of *Climacog. peltifer* the association of the abundant zone fossil with the equally abundant and conspicuous *Dicranog. zigzag* is a distinctive feature.

The changes in the appearance of *Climacog. bicornis* at successive horizons are also useful indices of age; when it first makes its appearance in the zone of *N. gracilis* the familiar spines at the proximal end are merely small outgrowths from the two basal thecae. Gradually these spines become more conspicuous until in the zone of *Cl. peltifer* they are stout stiff structures with a slight downward tendency ; in the succeeding zone of *Cl. wilsoni*, however, the two basal thecae are entirely modified to spines which are thick downward curving structures.

CARADOCIAN-ASHGILLIAN ASSEMBLAGES.

ASHGILLIAN.

15. ZONE OF DICELLOGRAPTUS ANCEPS.
Dicellog. anceps, D. complanatus var. **ornatus ;** *Climacog. normalis,* **Cl. supernus ;** *Orthog. truncatus* var. *abbreviatus ; Glyptog. persculptus.*
Return to *Dicellograpti* of simple type, waning of *Diplograpti.*

14. ZONE OF DICELLOGRAPTUS COMPLANATUS.
Dicellog. complanatus ; Orthog. socialis ; Climacog. miserabilis. (Probably pathological, a dwarfed fauna.)

CARADOCIAN.

13. ZONE OF PLEUROGRAPTUS LINEARIS.
Pleurog. linearis ; *Leptog. flaccidus ; Dicellog. elegans, D. forchammeri ; Dicranog. ramosus ;* **Climacog. tubuliferous, Cl. styloideus ; Orthog. quadrimucronatus, O. pauperatus.**
Return to *Leptograpti* of simple type but associated with large *Orthograpti.*

12. ZONE OF DICRANOGRAPTUS CLINGANI.
Dicranog. clingani, *D. ramosus ;* **Dicellog. morrisi,** *D. elegans,* **D. caduceus ; Climacog. caudatus ; Orthog. calcaratus ; O. truncatus ;** *Leptog. flaccidus.*
Predominance of *Dicellog.* of complex type and large *Orthograpti.*

11. ZONE OF CL. WILSONI.
Climacog. wilsoni ; *Cl. scharenbergi ;* **Cl. bicornis** mut. ; **Orthog. vulgatus ; O. intermedius ;** *Dicranog. nicholsoni.*
" Burst " of large *Orthograpti.*

With the beginning of the Caradocian is found one of the most impressive if not actually the most impressive horizons in the whole graptolite succession. This is the great *burst* of *Orthograpti* of large size that characterizes the base of that system. In the zone of *Climacog. wilsoni* the zone fossil is only locally abundant, but the presence of swarms of *Orthog. vulgatus, O. intermedius,* and the *Cl. bicornis* with the large drooping spines clearly indicate the horizon with or without the zone fossil.

In the zone of *Dicranog. clingani*, the zone fossil itself is not very easy of recognition as it may be confused with *D. brevicaulis*, but the abundance of *Dicellog. morrisi*, the peculiar *D. caduceus*, *Cl. caudatus*, and the swarms of *Orthog. truncatus* with *O. calcaratus* define the horizon with precision. Moreover, this is the zone in which *Dicellograpti* and *Dicranograpti* occur in greatest profusion.

In passing to the higher horizon of *Pleurog. linearis* there is a return to the simpler type of Leptograptid cell as seen in *Leptog. flaccidus*, very common at this horizon and in *P. linearis*, though this fossil is not universally distributed. *Orthog. pauperatus*, *Cl. tubuliferous*, and above all the distinctive *Orthog. quadrimucronatus* are characteristic of this horizon.

The assemblage found in the zone of *Dicellog. complanatus* calls for some comment on account of its nature, for it is largely a dwarfed fauna and may be a purely pathological horizon ; it seems to be almost invariably associated with a Barren Mudstone type of sediment. When the sedimentation is more normal a different fauna is found[1] in which *Climacog. styloideus* is the commonest and most characteristic graptolite. *Orthog. pristis* also occurs and it seems likely that the horizon corresponds with the Swedish zone of *D. pristis.* Whether this is a sub-zone of the *P. linearis* zone or represents a still higher horizon cannot yet be stated definitely.

VALENTIAN ASSEMBLAGES.

UPPER.

25. ZONE OF MONOG. CRENULATUS.
Monog. crenulatus, *M. priodon, M. subconicus ; Ret. geinitzianus* var. **angustidens.**

24. ZONE OF M. GRIESTONIENSIS.
M. griestoniensis, *M. discus, M. marri, M. subconicus, M. priodon* (early mut.).

23. ZONE OF M. CRISPUS.
M. crispus, *M. exiguus, M. nodifer, M. discus, M. marri, M. priodon* (early mut.), *M. nudus ;* **Rast. distans.**

22. ZONE OF M. TURRICULATUS.
M. turriculatus, *M. exiguus, M. nodifer,* **M. becki, M. runcinatus,** *M. marri, M. nudus ;* **Rast. maximus, R. linnaei ;** *Cl. hughesi.*
Acme of *Monograpti* of " isolate " type.

21. ZONE OF M. SEDGWICKI.
Monog. sedgwicki, M. tenuis ; *Orthog. bellulus ;* **Climacog. scalaris,** *Cl. hughesi.*
Gradual predominance of *Monograpti* of " hooked " type.

---

[1] W. B. R. King, *Q.J.G.S.*, vol. lxxix, 1923, p. 492.

LOWER.

20. ZONE OF M. CONVOLUTUS.
Monog. convolutus, M. clingani, M. lobiferus ; Rastrites peregrinus ; Cephalog. cometa ; *Petalog. folium ; Orthog. bellulus ; Glyptog. tamariscus ; Cl. hughesi.*
Gradual evolution of *Monograpti* of "hooked" type. Acme of *Monograpti* of "lobate" type.

19. ZONE OF M. GREGARIUS.

SUB-ZONE OF M. ARGENTEUS.
Monog. argenteus, M. leptotheca, *M. gregarius, M. communis,* **M. triangulatus** mut. ; *Rastrites longispinus ; Glyptog. tamariscus, G. sinuatus ; Petalog. folium, P. palmeus* var. *latus ; Cl. hughesi, Cl. törnquisti.*

SUB-ZONE OF M. TRIANGULATUS.
Monog. triangulatus, **M. millepeda,** *M. communis, M. raitzhainiensis, M. gregarius ;* **Mesog. magnus ;** *Glyptog. tamariscus, G. sinuatus ; Petalog. palmeus* var. *latus ; Cl. hughesi, Cl. törnquisti.*

SUB-ZONE OF M. FIMBRIATUS.
Monog. fimbriatus, *M. gregarius, M. raitzhainiensis, M. triangulatus, M. incommodus ;* **R. approximatus ;** *Glyptog. tamariscus ; Petalog. palmeus* var. *latus ; Cl. hughesi ; Cl. törnquisti.*
Entrance of *Monograpti* of "isolate" and "lobate" type.

18. ZONE OF M. CYPHUS.
M. cyphus, M. sandersoni, *M. incommodus, M. atavus ; Cl. hughesi, Cl. törnquisti, Cl. rectangularis ; Dimorphog. confertus.*
Abundance of *Monograpti* of "old-fashioned" type.

17. ZONE OF ORTHOG. VESICULOSUS.
Orthog. vesiculosus ; *Mesog. modestus ; Monog. atavus ;* **Climacog. medius.** *Cl. rectangularis, Cl. hughesi ;* **Dimorphog. swanstoni,** *D. confertus,* **D. extenuatus.**
Entrance of *Monograptus.*

16. ZONE OF CEPHALOG. ACUMINATUS AND GLYPTOG. PERSCULPTUS.
Cephalog. acuminatus ; *Glyptog. persculptus ; Orthog. truncatus* var. *abbreviatus ; Mesog. modestus* and var. *parvulus ;* **Climacog. normalis** mut.

In the assemblages belonging to the Valentian the first noteworthy thing is the entrance of *Monograptus* at the base of the zone of *Orthog. vesiculosus* in company with various *Dimorphograpti,* and the highly characteristic and easily recognized *Orthog. vesiculosus* itself ; the commonest *Climacograptus* at this horizon is *Climacog. medius,* which unfortunately is frequently confounded with *C.*

rectangularis, a form which is far commoner in the zone of *Monog. cyphus* and higher zones.

Professor Jones [1] divides these lower Valentian zones somewhat differently, separating off the zone of *Glyptog. persculptus* from that of *Cephalog. acuminatus*, and dividing the zone of *Orthog. vesiculosus* into two, a lower zone of *Monog. atavus* and an upper of *Monog. acinaces*. It does not seem possible always to separate the two lower zones satisfactorily either in S. Scotland or in certain areas in N. Wales, where indeed *Mesog. modestus* is often by far the commonest graptolite through all the lower beds, so they are here grouped together. A similar difficulty holds with regard to the zone of *Orthog. vesiculosus*, which as a single zone is very easily recognizable, but in which the two sub-zones do not seem to be so distinct in all localities. It does, however, appear that some subdivision of the zone of *Monog. gregarius* is advisable, though many species of graptolites range through all three sub-zones into which it can be divided ; the following facts, however, appear to be clear : with the entrance of the *Monograpti* in which the " lobate " and isolate trend is first discernible, there are still many *Monograpti* of the *incommodus* type. These are, however, confined to the lowest beds which may be conveniently separated off as the sub-zone of *M. fimbriatus* ; in the beds above *M. triangulatus* attains its maximum development together with *Monograpti* of more definitely lobate character ; in the succeeding beds for the first time *Monograpti* of the " hooked " type are developing and *Rastrites* are common, especially *R. longispinus*. This is the sub-zone of *Monog. argenteus* itself, a most characteristic and easily recognized form.

In the zone of *M. convolutus* it is not unusual to find a band in which *Cephalog. cometa* is very abundant. This, however, is apt to be merely a local feature ; in addition to the zone fossil the most characteristic graptolites indicative of this horizon are *M. lobiferus* and *Rastrites peregrinus*.

The characteristic feature of the Upper Valentian is the gradual predominance of the " hooked " *Monograpti* as the " lobate " types wane. Thus *M. sedgwicki* is followed by *M. marri*, which leads into the early forms of *M. priodon* ; the " lobate " forms *M. becki*, *M. exiguus* and *M. crispus* are only found in the lower zones.

The form of *M. turriculatus* is sufficiently distinctive for the recognition of the zone in which it occurs, as is also *R. maximus*, with which it is usually associated, though the latter fossil is apt to occur chiefly in bands in the lower part of the zone. The form of the rhabdosome in *M. crispus* is also highly characteristic, as is also that of *M. discus*, which is a very useful little fossil, as its range is restricted and it is often abundant.

---

[1] O. T. Jones, *Q.J.G.S.*, vol. lxv, 1909, p. 468 ; *Q.J.G.S.*, vol. lxxvii, 1921, p. 153.

SALOPIAN (LUDLOW) ASSEMBLAGES.

36. ZONE OF M. LEINTWARDINENSIS.
Monog. leintwardinensis and var. **incipiens.**

35. ZONE OF M. TUMESCENS.
Monog. tumescens.

34. ZONE OF M. SCANICUS.
Monog. scanicus, *M. roemeri, M. dubius.*

33. ZONE OF M. NILSSONI.
Monog. nilssoni, M. colonus, M. bohemicus, *M. dubius,* **M. orbatus,** *M. roemeri ;* **Retiolites spinosus.**

32. ZONE OF M. VULGATUS.
M. vulgatus, *M. dubius, M. flemingii.*
Retrogression, waning of *Monograpti* of "hooked" type, with return to *Monograpti* of "old-fashioned" type.

SALOPIAN (WENLOCK) ASSEMBLAGES.

31. ZONE OF CYRTOG. LUNDGRENI.
Cyrtog. lundgreni ; *Monog. flemingii* and var. **compactus, M. testis,** *M. dubius, M. vomerinus.*

30. ZONE OF CYRTOG. RIGIDUS.
Cyrtog. rigidus ; *Monog. flemingii* and var. *primus,* **M. retroflexus,** *M. dubius, M. vomerinus.*

29. ZONE OF CYRTOG. LINNARSSONI.
Cyrtog. linnarssoni ; M. flexilis, *M. flemingii* var. *primus, M. priodon, M. dubius, M. vomerinus.*

28. ZONE OF CYRTOG. SYMMETRICUS.
Cyrtog. symmetricus ; M. capillaceus, *M. priodon, M. dubius.*

27. ZONE OF MONOG. RICCARTONENSIS.
Monog. riccartonensis ; M. capillaceus, *M. priodon, M. dubius ;* **Cyrtog. flaccidus.**

26. ZONE OF CYRTOG. MURCHISONI.
Cyrtog. murchisoni ; *M. priodon, M. vomerinus* and var. **gracilis,** *M. basilicus ;* **Ret. geinitzianus.**
Acme of *Monograpti* of "hooked" type. Entrance of *Cyrtograpti.*

In the Wenlock division of the Salopian many graptolites are common to the different horizons, but different *Cyrtograpti* are characteristic, and there seems to be little doubt that in general *M. flemingii* represents a retrogression from *M. priodon,* and hence is more particularly found in the upper Wenlock zones, whilst *M. priodon* belongs more particularly to the lower.

In the Ludlow division of the Salopian the most widespread and best developed zone over wide areas is unquestionably the zone of *M. nilssoni.* The characteristic zone fossil is usually accompanied by a long form of *M. dubius*, by *M. bohemicus*, a large form of which is abundant in the lower parts of the zone, and by the true *M. colonus*. It is not always easy to separate off the zone of *M. vulgaris* in the north of England. The zone of *M. scanicus*, too, requires careful differentiation outside the Welsh Borderland, but the two succeeding horizons, those of *M. tumescens* and *M. leintwardinensis*, since they are nearly monotypic, can as a rule be recognized with ease.

NOTE.—In the Sedgwick Museum at Cambridge there are at present cases arranged to show the succession of the British graptolite zones with the commoner assemblages characteristic of each horizon ; upon application to the Woodwardian Professor, permission to study these will be given to any *bona fide* geologists who desire to do so.

On Some Specimens of Fossiliferous Sandstone from Pahang, Malay Peninsula.

By JOHN WEIR, M.A., Ph.D., Geological Department, University of Glasgow.

IN 1900 Mr. R. Bullen Newton described the casts and impressions of some lamellibranch shells, in blocks of fossiliferous sandstone from Kuala Lipis, Pahang.[1] On account of the prevalence of specimens which he assigned to the genus *Myophoria*, Mr. Newton called the rock " Myophorian Sandstone ". Amongst other species identified by Mr. Newton *Chlamys valoniensis* has a wide distribution, " and is characteristic of the Rhaetic or uppermost Trias. It is to this horizon, therefore, that the Myophorian Sandstone must be referred ".

More recently, Mr. Newton has described a fauna from Mount Faber, Singapore.[2] The material was collected by Mr. J. B. Scrivenor, the Government Geologist of the district, and the fauna is similar to that from Pahang—both are characterized by the predominance of *Myophoria* spp., and they have several forms in common. These are :—

Chlamys valoniensis (Defrance-Leymerie) ; *Myophoria ornata*, Wissmann ;
Modiolopsis gonoides, Healey (= *Pleurophorus elongatus* ? R. B. Newton).

Moreover, the sandstones are similar lithologically, and Mr. Newton thinks that they may form a single geological horizon extending from Pahang to Singapore.

The Hunterian Museum of Glasgow University has recently acquired a few specimens of fossiliferous sandstone from Pahang.

---

[1] " On Marine Triassic Lamellibranchs Discovered in the Malay Peninsula," *Proc. Malac. Soc.*, iv, 1900, pp. 130–5, pl. xii.

[2] " On Marine Triassic Shells from Singapore," *Ann. and Mag. Nat. Hist.*, 9, xii, 1923, pp. 300–21, pl. ix.

These specimens were collected in 1902–3 by Mr. Cecil Wray near Kuala Lipis, in a cutting on the main road from Selangen. They are apparently similar to those described by Mr. Newton from the same neighbourhood—the rock is soft, of a light fawn colour, and the impressions and casts are tinted reddish, probably with iron. All the fossils are lamellibranchs, and those which may be identified with certainty are co-specific with forms from Kuala Lipis assigned by Mr. Newton to *Myophoria* spp.

In the present instance one cast reveals a slit beneath the umbo, which is probably the impression of the anterior myophorian tooth. A similar feature is recorded by Mr. Newton. There is no other evidence of the myophorian hinge in the present specimens, but on the basis of secondary generic characters I think they may be assigned to *Myophoria*. The species are :—

M. ornata, Münster ; *M. inaequicostata*, Klipstein ; *M. malayensis*, Newton ; *Myophoria* allied to *M. malayensis*, Newton.[1]

In addition there is a cast, probably co-specific with one of the indeterminable specimens figured by Mr. Newton.[2] The cast is elongate-ovate in outline, but is probably incomplete posteriorly. There are six strong ribs, separated by wide interspaces ; the fourth rib from the anterior end is the most prominent.

There is also the impression of a lamellibranch valve, probably a *Halobia*, which was submitted to Mr. Newton for examination, because of his recent important contribution to our knowledge of that genus in the Malay States.[3] Mr. Newton writes : " It very probably belongs to the genus *Halobia*, although too poorly preserved for accurate determination. The dorsal margin on which so much depends is entirely absent through fracturing . . . the presence of radial striations is very doubtful." The approximate dimensions of this individual would be : Length, 34 mm. ; breadth, 40 mm.

There is also a cast, identical with that designated *Pleurophorus elongatus* ? by Mr. Newton, and later referred to *Modiolopsis gonoides* by Miss Healey, who recognized in Mr. Newton's Pahang specimen the species from the Napeng Beds of Burma, which was first described by her under that name.

In both the papers mentioned above Mr. Newton, on the evidence available, regards the beds concerned as of Upper Triassic or Rhaetic age. Mr. Newton has recorded a total of twenty-nine forms from this Myophorian Sandstone horizon. On analysis it is found that seven species are characteristic of the St. Cassian Beds of the Tyrol (or have their nearest affinities in St. Cassian species). These are : *Promathildia colon* (Wissmann) ; *Spondylus dubiosus* (Bittner) ;

---

[1] Loc. cit., 1900, pl. xii, fig. 11.

[2] Loc. cit., 1923, pl. ix, fig. 7.

[3] " On Marine Triassic Fossils from Kedah and Perak," GEOL. MAG., LXII, 1925, pp. 76–85, Pl. III. " Fauna of the Napeng Beds," *Pal. Indica*, n.s. ii, mem. 4, 1908, pp. 51–3, pl. vii.

Cassianella cf. *tenuistria* (Münster); *Palacocardita* cf. *crenata* (Goldfuss); *Myophoria ornata*, Wissmann; *M. bittneri*, Newton; *Opis* cf. *hoeninghausi* (Klipstein).

Two forms have affinities with species which range from the St. Cassian into the Raibl Beds: *Schafhaütlia astartiformis* (Wissmann); *Myophoria inaequicostata*, Klipstein.

Three forms have affinities to Muschelkalk species: *Prospondylus comtus* (Goldfuss); *Myophoria* cf. *goldfussi*, Alberti; *Spiriferina* cf. *fragilis* (Schlotheim).

Five forms have affinities to Rhaetic species: *Chlamys valoniensis* (Defrance-Leymerie); *Syncyclonema* sp. (probably related to *S. quotidianus*, Healey, from the Rhaetic of Burma and Tonkin); *Modiolopsis gonoides*, Healey; *Gervillia inflata*, Schafhaütl; *Mytilus* sp. (allied to *M. minutus*, Goldf.).

In addition to the above, five species are new, and six are indeterminable; one form is related to *Lopha montis-caprilis* (Klipstein), which ranges from St. Cassian to Rhaetic.

It will be seen from the above analysis that the fauna is predominantly St. Cassian in its affinities. Excepting the new species there are eighteen determinable forms; of these thirteen have affinities with species which occur definitely below the Rhaetic in Europe and in Asia. The characteristic Triassic genus *Myophoria* is represented by nine forms; it is true that three of these are indeterminable, but they almost certainly belong to three different species. In view of the predominance of infra-Rhaetic species, the richness of the genus Myophoria in species (and also in individuals—these being very abundant in the Hunterian Pahang collection), it seems desirable meantime to regard the age of these deposits as Upper Trias (i.e. infra-Rhaetic).

A collection of marine molluscan shells and terrestrial plant remains was made by Mr. Scrivenor at Mount Guthrie, Singapore, and described by Mr. Newton in 1906.[1] This association suggests an estuarine or lagoon origin for the beds, which Mr. Scrivenor thinks may be correlated, on strike and petrological characters, with the Tembeling shale and sandstone series of the Malay Peninsula; this series includes the Myophorian Sandstone horizon of Pahang and Singapore (Mount Faber). The material included some new species of lamellibranchs, of which two were assigned to the genus *Goniomya*; among the plant remains occurred a leaf-like body which Mr. Newton referred to *Podozamites*, and a seed referred to *Carpolithes*. Mr. Newton offered the suggestion that the Mount Guthrie deposits might therefore be an extension of the Upper Gondwana deposits of India, and of Bajocian age. According to Mr. Scrivenor's interpretation of the field evidence, the Mount Faber Beds are on a higher horizon than the Mount Guthrie Beds. This contradicts the palaeontological evidence as interpreted by Mr. Newton, but the Mount Guthrie material is unsatisfactory; as Mr. Scrivenor points out,[1] *Podozamites* ranges, according to Nicholson and Lydekker, from Rhaetic into Cretaceous, and Mr. Newton cites occurrences of *Goniomya* in Palaeozoic rocks.

---

[1] Geol. Mag., 1906, pp. 487–96, Pl. XXV.

In his most recent paper on this region (loc. supra cit.) Mr. Newton, in addition to describing new material, revises Professor T. Rupert Jones' determination of a bivalve from the Tembeling series of Perak. This bivalve Professor Jones determined as[2] *Estheriella radiata* (Salinas) var. *multi-lineata*, but the new material from the adjacent province of Kedah has enabled Mr. Newton to establish the fact that it is really a lamellibranch comparable to *Halobia moussoni* (Merian). On the basis of this determination Mr. Newton suggests that the Kedah-Perak facies of the Tembeling series is of Middle Triassic (Anisian and Ladinian) age, and therefore probably older than the Myophorian Sandstone.

The absence of the Rhaetic zone fossil *Pteria contorta* affords negative evidence in favour of regarding the Myophorian Sandstone as not of Rhaetic age. *Pt. contorta* has been recorded from Burma, where it has a wide distribution in the Napeng Beds, and in which it is associated with an entirely different marine assemblage, the only species common to the Myophorian and Napeng faunas being *Modiolopsis gonoides*, Healey. Moreover, the Malayan specimens assigned to this species are imperfect natural casts, with no trace of ornamentation. Finally, in Tonkin and Yunnan faunas of St. Cassian affinities co-exist with *terrestrial* Rhaetic deposits. By analogy, terrestrial Rhaetic deposits might be expected to exist in the latitude of Pahang—they may lie some distance to the East and be now buried in the waters of the China Sea.

The bulk of the evidence available, therefore, seems to indicate an infra-Rhaetic age for the Tembeling series.

On Some English Species of the Genus *Stylophyllopsis*.

By S. H. STRAW, M.Sc., F.G.S., Victoria University, Manchester.

I. INTRODUCTION.

THE three species of corals which form the subject of this communication are all from the Lower Lias of the west and centre of England. They were originally described by Duncan[3] as species of *Montlivaltia*, viz. *M. rugosa*, *M. mucronata*, and *M. victoriae*. But in 1890 it was suggested by Frech[4] that many of the so-called *Montlivaltia* and *Thecosmilia* from the English

---

[1] GEOL. MAG., 1908, p. 291.

[2] "Note on a Triassic *Estheriella* from the Malay Peninsula," GEOL. MAG., 1905, pp. 50–2, Pl. II.

[3] "Suppt. Brit. Foss. Cor.," pt. iv, 1868, *Mon. Pal. Soc.*

[4] "Die Korallenfauna der Trias," *Palaeontographica*, vol. xxxvii.

Lias should be included in the genus *Stylophyllopsis*, established by him in that year for certain Triassic corals which possessed in their septal structure, and in other features of lesser importance, characters sufficiently distinctive to justify their separation from *Montlivaltia*. Owing, however, to the absence from Duncan's monograph of satisfactory representations of transverse and longitudinal sections, the generic determination of the English forms remained in every case uncertain.

As a result of the present investigation the writer has been able to confirm the opinion of Frech, at least so far as the species dealt with are concerned, and, further, to describe the more minute details of septal structure, which Frech, owing to the less perfect state of preservation of his material, was unable to observe.

The genus *Stylophyllopsis* includes simple or slightly branching forms with a well-developed epitheca, endothecal tissue in the form of coarse dissepiments and tabulae, and septa composed of coarse thick trabeculae, ornamented with irregularly distributed granulations. In the peripheral and middle portions of the septa the trabeculae are more or less closely united, but near the centre of the coral the inner trabeculae become detached and form an irregular group of detached spines. The amount of detachment varies considerably in different species and often also among the members of a single species.[1]

In all these characters *Stylophyllopsis* differs from *Montlivaltia* in which the septa are in the form of complete lamellae ; the septal granulations occur in well-defined rows and the dissepiments, when present, are fine and generally more abundant.

II. DESCRIPTION.

Stylophyllopsis rugosa (Duncan and Wright).

Thecocyathus rugosus Wright MS.

Montlivaltia rugosa Duncan and Wright, 1868, non Muenster, 1841.

Stratigraphical Horizon.—Late *raricostatus* and early *armatus* zones of Gloucestershire, etc.

External Characters.—The corallum arises from a broad base of attachment and is frequently very irregular in shape, but in spite of the great variation in form the Pedunculate and Trochoid shape-stages[2] may always be recognized. In many coralla the Trochoid stage is repeated a number of times as the result of rejuvenescence. (Fig. 1.) Most of the irregularities in shape are due to the ill-fitting manner in which the successive Trochoid stages rest on one another.

The *epitheca,* owing to its poor state of preservation, usually appears smooth or with transverse growth lines only. In better

---

[1] Cf. Frech's figures of *Stylophyllopsis lindströmi* ; Frech, op. cit., taf. figs. 15–20.

[2] W. D. Lang, "Growth Stages in the British Species of the Coral genus *Parasmilia*," *Proc. Zool. Soc. Lond.*, 1909.

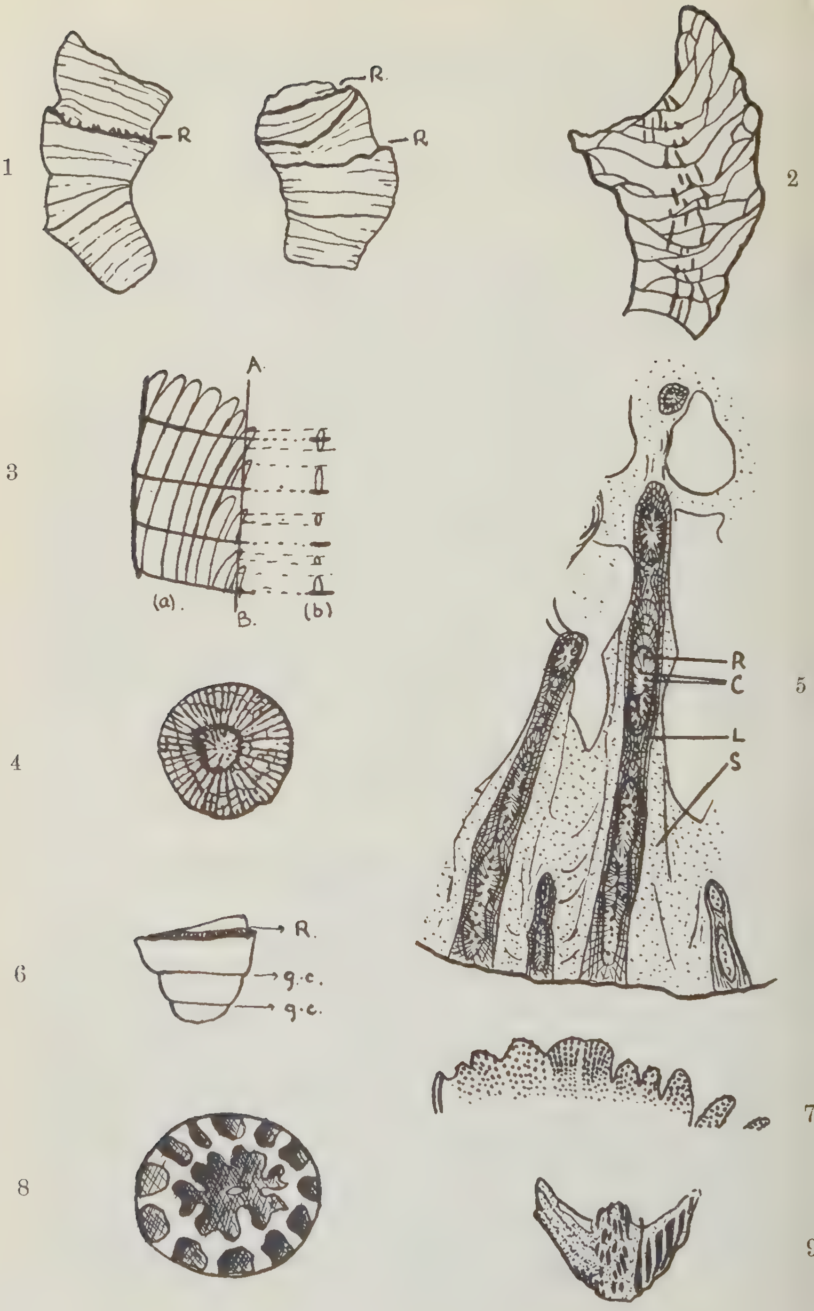

FIG. 1.—*Stylophyllopsis rugosa* (Nos. 1–5) and *S. mucronata* (Nos. 6–9).

preserved specimens, however, it is seen to be ornamented with longitudinal striae. These are rather flat in cross section, and under a strong lens are seen to bear a still finer ornament of longitudinal lines.

The *septa*, as seen in the calyx, are coarsely trabeculate in character. The trabeculae end superiorly in rounded or pointed septal teeth. There are usually about seven visible in the calyx in the primary septum of an adult. The trabeculae are separated by grooves which peripherally are usually quite faint, but which become successively more marked when traced inwards along the face of the septum. Near the centre of the coral the innermost trabeculae become detached from the rest of the septum.

The trabeculae (and the septal teeth) are not vertical but follow an upward and inward course.

The *septal ornament*, according to Duncan, consists of wavy lines and is so figured by him, but from the examination of a number of calices in which the septa are tolerably well-preserved, it is evident that the septal ornament of this species is in the form of granulations irregularly distributed over the sides of the trabeculae and the septal teeth. The specimen figured by Duncan was probably weathered.

In specimens which have lost the epitheca the outer edges of the septa, except sometimes those of the last cycle, are seen as continuous lines down the coral, and the interseptal spaces are crossed by coarse and more or less horizontal dissepiments which frequently, from their disposition in horizontal rows, assume the appearance of tabulae.

Internal Characters.

Longitudinal sections. (Fig. 2.)—The endothecal tissue is in the form of tabulae and dissepiments. The tabulae are concave to the calyx and often extend right across the visceral space. The dissepiments are large and convex inwards, and only occur near the sides.

In sections which do not pass through the middle the septa are continuous for the whole of their length, but in median sections the inner septal edges are discontinuous. The discontinuous portions vary in their relation to the tabulae. Some rest on the upper surfaces of the latter, others occur in isolated condition between them, whilst others extend through them. All three conditions may usually be seen in a single section.

The discontinuity is due partly to the fact that in the central region the successive tabulae were laid down above the upper septal edges of the previous growth period, and partly to the detached condition and inward curvature of the innermost trabeculae. Fig. 3*a* illustrates diagrammatically the condition of the inner septal edge. In the plane of a section down *A.B.* the inner septal edge would appear as shown in Fig. 3*b*.

Transverse sections. (Fig. 4.)

A radial hexameral arrangement of the septa is evident in most sections, but the order is occasionally irregular. Generally there are four complete cycles and representatives of a fifth ; rarely, five complete cycles.

The central region is occupied by a small irregular group of detached trabeculae, but as these are usually embedded in stereoplasm their detached condition is not always evident.

Peripherally there appears to be a thick wall, but this is due to the filling of the interseptal spaces by stereoplasm. In this deposit the members of the last cycle of septa are frequently completely buried.

Between the central region and the " wall " the interseptal loculi are occupied by a few coarse dissepiments.

Microscopic structure of the septa. (Fig. 5.)

The state of preservation of some of the specimens has been sufficiently good to show details of the minute structure of the septa when examined in thin sections under the low power of a microscope. In any septum, three elements of structure may be observed :—

1. *" Centres of Calcification."*

The central portion of each trabecula contains a number of points which may be either deep brown in colour and more or less opaque or, very bright and transparent, according to their state of preservation. These are the " centres of calcification " of Fowler,[1] Ogilvie,[2] and other writers. They correspond to the " dark-line " or " primary streak " observed in the middle of transverse sections of the septa of certain other corals (e.g. Zaphrentis).[3] Their arrangement in the trabecula depends on the shape of the cross section of the latter.

Near the centre of the coral the trabeculae are almost circular in cross section and only loosely bound together. In these the " centres of calcification " show a radial arrangement about an imaginary point at the centre of the trabecula. Passing outwards from the centre the trabeculae become more closely attached and oval in shape, and the " centres " are drawn out round the major diameter of the oval. Near the periphery in most septa two or three trabeculae are fused into a compact lamella, in which the points are still further drawn out into an irregular or zigzag line.

The " centres of calcification " are really sections through " axes of calcification " which, from an ideal axis running down the centre of the trabecula, diverge in an upward direction to its outer surface.

---

[1] Fowler, " Anatomy of the Madreporaria," III, *Q.J. Micr. Soc.*, 1887.

[2] Ogilvie, " Microscopic and Systematic Study of Madreporarian Types of Corals," *Phil. Trans. Roy. Soc.*, Series B, vol. clxxxvii, 1896, p. 113, etc.

[3] Cf. Nicholson and Lyddeker, *Manual of Palaeontology*, vol. i, 1889, p. 247.

Such trabeculae are of the *compound, radio-symmetric* type of Dr. M. M. Ogilvie.[1]

2. *Radiating fibrous deposit.*

The body of each trabecula is composed of a fibrous deposit, the fibres radiating from the " centres of calcification " to its outer edge. Each centre has its own bundle of fibres, termed by Dr. Ogilvie a " fascicle of fibres ", each of which, where it emerges on the lateral surface of the trabecula, forms a granulation.[2]

The arrangement of the granulations, therefore, on the exterior, bears a definite relation to the internal arrangement of the fascicles of fibres of the trabecula. In between the individual trabeculae there appear to be isolated " centres of calcification " with associated radial fibres, but whether these belong to the trabeculae and have a wide angle of divergence from the imaginary axis in the middle, or whether they represent material independently deposited in between the trabeculae, is not clear.

3. *Lamellar fibrous deposit.*

On both faces of the septum and outside the trabeculae, apparently binding them together, is a fibrous deposit arranged in separate lamellae. The direction of the fibres is towards the centre of the trabecula they surround, i.e. they continue the direction of the fibres of the trabecula itself. This deposit is thinnest over the lateral surfaces of the trabeculae and increases to a maximum in the inner-trabecular grooves, thus giving a more uniform thickness to the septum as a whole.

The original septum has been secondarily thickened by a deposit of stereoplasm. This is also fibrous in character but the fibres do not appear to have any regular arrangement. In places it is imperfectly lamellate and is not distinctly marked off from the " lamellar fibrous deposit ". It covers the faces of the septa and is especially thick peripherally where the deposit of adjoining septa often unites to form a continuous deposit across the interseptal space, giving the appearance of a thick wall or pseudotheca. From here it thins out along the faces of the septa, but in the central region it again thickens and forms a massive deposit surrounding the detached trabeculae of the inner ends of the larger septa.

The investigation of the structure of this species leaves no doubt as to its generic position, for it has been shown to possess all the characteristic features of *Stylophyllopsis* Frech, namely :—

(1) The large size and coarse character of the trabeculae.

(2) The presence of detached trabeculae in the central region as indicated in transverse and longitudinal sections.

(3) The irregular distribution of the granulations over the surface of the septa.

(4) The coarseness of the dissepimental tissue.

---

[1] Ogilvie, op. cit., pp. 141, 153.

[2] Ibid., p. 118, and fig. 9.

Stylophyllopsis mucronata (Duncan).

Montlivaltia mucronata Duncan, 1868.

Stratigraphical Horizon.—This species has been recorded from the zone of *Amm. jamesoni* of several localities in the west and centre of England. Most of the details of internal structure have been worked out from specimens collected at Old Dalby, Leicestershire, and the results have been confirmed from sections cut from specimens from the type locality (Fenny Compton, Oxfordshire) in the British Museum, Nat. Hist. and the Geological Survey Museum, Jermyn Street, London.

External Characters.—This species is short with only a small base of attachment. It is very variable in form, but rarely, if ever, passes beyond the Trochoid stage. A specimen figured by Duncan[1] approaches the Cylindrical stage, but out of some hundreds of specimens examined not one shows a similar approach. Constrictions due to rejuvenescence occur in many specimens. In others, on the other hand, there is no visible sign of the process. Growth constrictions are, however, of general and frequent occurrence. They are narrow but distinct horizontal grooves, each of uniform depth, all round the coral marking the interval between successive " bourrelets d'accroissement ". They are more frequent and more strongly marked in the lower half of the coral, where they are found at intervals of a few millimetres. (Fig. 6.) The uniformity of their appearance and the absence of any associated discontinuity of the epitheca serve to distinguish them from the constrictions due to rejuvenescence. These are generally more strongly marked on one side of the coral than on the other and cause a definite interruption in the continuity of the skeletal structure—the upper edges of the outer portions of the septa of the old calyx extending beyond the outer limits of the rejuvenated portion. (See Fig. 6.)

The *epitheca* is ornamented with rounded longitudinal striae and fine transverse (growth) lines. The striae are separated into groups of eight (except in the early stages, when there are fewer) by shallow longitudinal grooves, which correspond in position to the septa of the first two cycles. In the lower part of the coral the groups are arched into longitudinal ribs of which there are normally twelve in number. Passing upwards the ribs bifurcate and become fainter, often dying out before reaching the margin of the calyx. The striae also become gradually flatter and fainter until at the upper margin they are often barely or not at all visible.

The *septa* in well-preserved calices are seen to be of similar structure to those of *S. rugosa* : they are coarsely trabeculate and the innermost trabeculae are detached and bend inwards towards the centre. In this species, however, owing to its larger diameter, the number of trabeculae forming a primary septum is greater, varying from eight to ten according to the diameter of the calyx. The detached central trabeculae are also more numerous and they form a definite columellary structure projecting slightly into the calyx in mature specimens.

---

[1] Duncan, *Suppt. Brit. Foss. Cor.*, pt. iv, pl. xiv, fig. 18.

It is seldom that the upper septal edge is completely preserved, but this occurs in a large specimen (No. 37101) in the Museum of Practical Geology. The upper portion of one of the septa of this specimen is represented in Fig. 7.

The highest point of the septum is about two-thirds of the distance from the centre to the periphery. The two trabeculae forming this part of the septum are longer, more compressed-elliptical in cross section, and more closely united than any of the others. On either side of them the remaining trabeculae diverge and become successively shorter and rounder until those that are detached in the centre of the coral are circular in section. These latter, however, increase in length and curve rapidly inwards. Along with the change in shape goes a change in arrangement of the septal granulations. The round trabeculae have them irregularly arranged, but as the trabeculae become successively more compressed the granulations tend more and more to be arranged in lines. In the longest trabeculae they are quite definitely arranged in this manner. This specimen is one of the largest and best developed examples of *S. mucronata* the writer has met with. In younger specimens the linear arrangement of the granulations is never well shown, but the tendency is always present in the trabeculae in the middle region of the septum.

Early growth-stages.—The earliest growth-stage known to the writer is shown by a very young corallite (Fig. 8) attached to the outside of an older one. Resting on a basal epitheca 1·5 mm. in diameter are twelve small septa radially arranged in two cycles. Those of the first cycle consist of three short trabeculae, but those of the second cycle of two trabeculae only. The middle trabeculae of the septa of the first cycle are thickened laterally and unite with the similarly thickened inner trabeculae of the septa of the second cycle to form a distinct wall (pseudotheca) 1 mm. in diameter. The inner trabecula of some of the first cycle septa is detached and in the centre of the calyx there is a single isolated spine. The whole corallite at this stage is of less diameter than the base of attachment of older individuals. When the scar of attachment of older individuals is cleaned the under side of the wall formed at this very early stage is seen as a small ring. Occasionally two rings arranged concentrically may be observed indicating that an increase in diameter was accompanied by the development of a second wall of larger diameter outside the earlier one. A similar method of growth in very early stages has been observed in *Montlivaltia trochoides* and *Montlivaltia caryophyllata* and is also recorded by Tomes[1] as occurring in "*Montlivaltia*" *victoriae.*

---

[1] *Q.J.G.S.*, 1884, p. 709.

Internal Characters.

Longitudinal sections. (Fig. 9.)—The middle of the coral is occupied by a sheaf of detached trabeculae embedded in stereoplasm and forming the broad columellary structure. The latter is not equally well developed in all specimens. In some it is quite rudimentary; in others, especially the larger and better developed examples, it forms a prominent feature in longitudinal sections. It is well developed in the specimen of Fig. 9.

The endothecal tissue appears to consist solely of laminar stereoplasm, but in this a few coarse tabulae are buried. The tabulae are not always distinguishable. That they are actually present is proved by the examination (*a*) of weathered specimens, and (*b*) of sections in which the endothecal tissue has undergone partial recrystallization. In the former the tabulae stand out conspicuously owing to the relative ease with which the stereoplasm is removed by the weathering agents. In the latter the process of recrystallization has likewise affected the stereoplasm more readily than the tabulae, which have remained unaltered and are readily recognized. The tabulae, unlike those of *S. rugosa*, do not appear to cross the centre, but terminate at the boundary of the columella.

Longitudinal sections obtained by fracturing specimens down the middle illustrate clearly the macroscopic septal characters of the species. Such a section is represented by Fig. 10. It will be observed that there is no vertical discontinuity of the detached trabeculae in this species. The specimen figured is immature and does not show the linear arrangement of the septal granulations seen in more mature specimens.

Transverse Sections. (Fig. 11.)—These resemble those of *S. rugosa* except that—

(*a*) there are no dissepiments, and in sections below the floor of the calyx the interseptal spaces are usually completely filled with stereoplasm;

(*b*) in fully developed specimens the fifth cycle of septa is complete and portions of a sixth cycle may be present; and

(*c*) the detached central trabeculae are far more numerous. Further, the details of septal microstructure as seen in transverse section are essentially identical in both species. (Fig. 12.)

Stylophyllopsis victoriae (Duncan).

Montlivaltia victoriae Duncan, 1868.

Stratigraphical Horizon.—Capricornus zone, Cherrington (Oxfordshire) and Grimsbury, near Banbury.

External Characters.—In a number of respects this species closely resembles *S. rugosa*; it has a broad base of attachment, is remarkably polymorphic, has an epithecal ornament of rather flat longitudinal striae, and, where the epitheca is worn away, is seen to possess

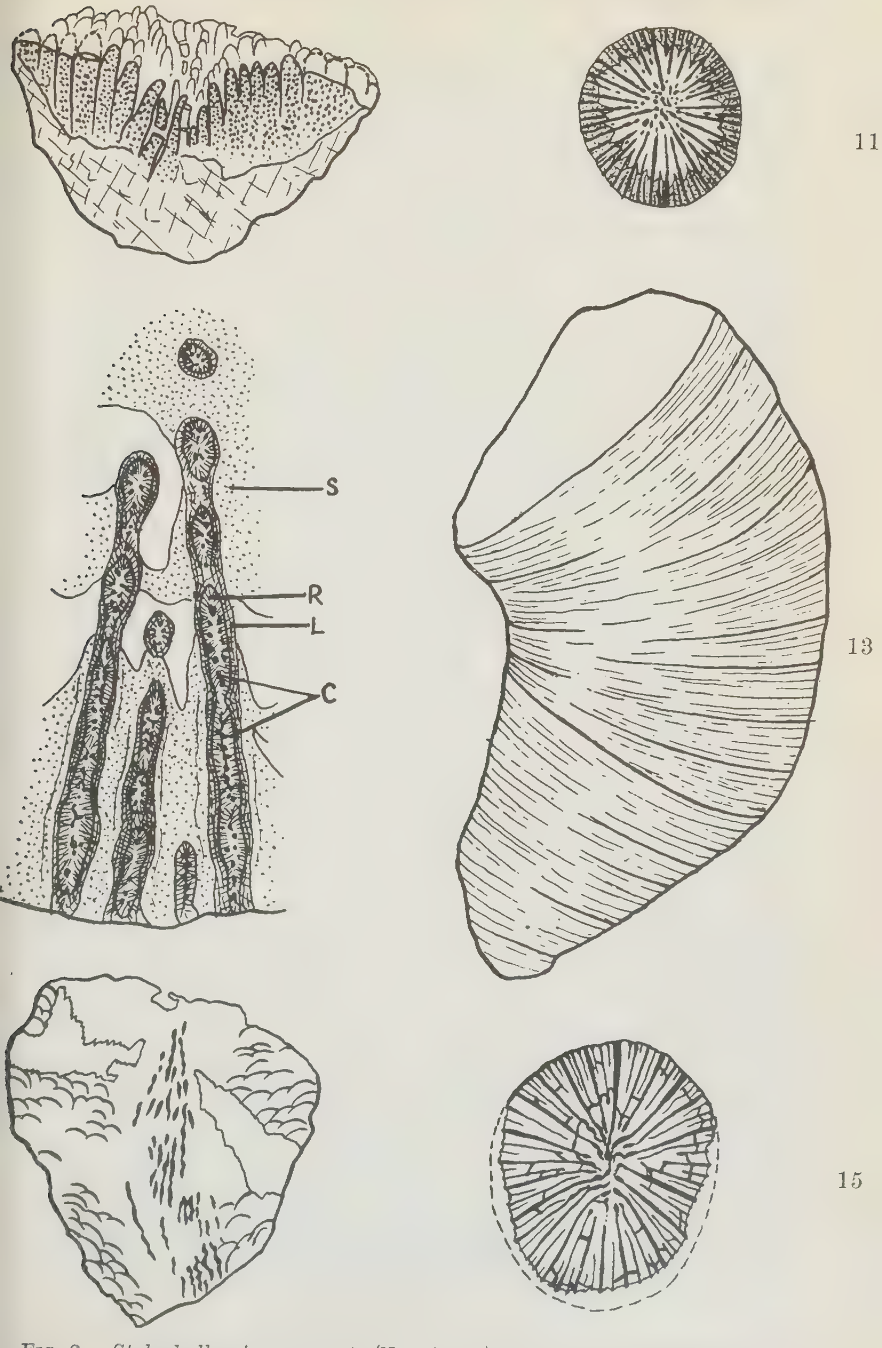

FIG. 2.—*Stylophyllopsis mucronata* (Nos. 10–12) and *S. victoriae* (Nos. 13–15).

coarse dissepiments which have a tendency to an arrangement in horizontal rows.

It differs, however, in its great size (it is the largest British Liassic simple coral) and in the attainment by fully developed individuals of a well-marked Cylindroid shape-stage. (Fig. 13.)

Constrictions due to rejuvenescence appear to be absent. When, as in most specimens, the septal teeth are broken off, the trabeculate character of the septa is only evident towards their inner ends. Intertrabecular grooves are absent over most of the septal face so that the septa are more leaf-like than those of the two previously described species.

The septal ornament is rarely seen, since in most specimens the original calcium carbonate of the skeleton has undergone recrystallization with consequent obliteration of the finer details of septal structure. The septal teeth are only occasionally preserved. Those near the centre are round and covered with irregularly distributed granulations, but the remainder are very much compressed laterally and the granulations are in parallel vertical rows as in *Montlivaltia.*

Internal Characters.

Longitudinal Sections. (Fig. 14.)—The inner septal edges are made up of the tips of numerous trabeculae which, owing to their fan-like disposition in the septum, take up their position at the inner septal edge, one above the other. But in this species, whilst some of the trabeculae become detached and form separate spines along the inner septal edge, others remain loosely attached right to the edge and appear in sections as continuous lines with a somewhat moniliform appearance.

Tabulae are absent. The visceral space presents a coarsely vesicular appearance due to the abundant development of large dissepiments convex to the calyx.

Transverse Sections. (Fig. 15.)

Six cycles of septa are developed, the last being very small. For the greater part of their course from the periphery inwards the septa are simple, straight lamellae formed by the coalescence of the trabeculae. They are thickest near the periphery and become steadily thinner passing inwards until near the inner end, where they thicken again and become lobular owing to the tendency to detachment of the inner trabeculae. The latter are rarely completely detached and in many sections no detached trabeculae are present. Only the septa of the first two cycles reach the centre. Here these meet not at a point but along a narrow elongated central fossa. Occasionally some of the septa extend across the fossa. Further, in some of the larger specimens the inner septal ends tend to curl round one another to form a rudimentary false columella.

Dissepiments are not abundant in transverse sections and there is very little stereoplasm in the interseptal loculi.

Usually the state of preservation is too poor to show any details of septal micro-structure. Occasionally, however, radiating fibres running from a small group of " centres of calcification " are visible. At other times an irregular line of " centres " may be fairly clearly discerned in the middle and outer portions of a septum. A thin coat of secondary thickening is usually present on the faces of the septa. There seems to be little doubt, therefore, that in their original state the septa were composed of trabeculae of the compound, radiosymmetric type, which, however, by coalescence formed compact lamellae.

III. GENERAL CONCLUSIONS.

The main interest of the genus *Stylophyllopsis* lies in its septal structure. The septa in their more compact outer portions resemble those of *Montlivaltia,* but in their inner portions they recall the condition found in *Stylophyllum* in which the septal apparatus consists entirely of more or less isolated spines. The more advanced forms of *Stylophyllum* always show a certain amount of union of the spines into an incomplete septum, and there seems little doubt that *Stylophyllopsis* was derived from *Stylophyllum* by further coalescence of the septal spines into a more complete septum. In the majority of species of *Stylophyllopsis* the innermost spines (trabeculae) always remain detached, but in *Stylophyllopsis victoriae* they show very little tendency to detachment and the septa are only slightly less complete than those of *Montlivaltia.* They agree, moreover, in having in the compact portions similarly arranged septal granulations. This species, from its great size and the fact that it reaches a Cylindroid stage, may be regarded as an advanced form of *Stylophyllopsis.* We have, therefore, within the *Stylophyllum-Stylophyllopsis* group, definite indications of a progressive change in septal structure from isolated spines to an almost complete septum. Any further change in the same direction would lead inevitably to a form with a truly Montlivaltoid septum. Hence, although neither *Stylophyllum* nor *Stylophyllopsis* is at present known from beds later than the Lower Lias, it is possible that the stock continued to exist and that its representatives are at present included in *Montlivaltia.* But this genus is undoubtedly polyphyletic. The genotype *M. caryophyllata* Lamx. from the Bathian of Caen is a relatively small trochoid form of very simple structure, possessing only septa and epitheca. It has all the appearance of a stock in the early stages of its history and cannot be regarded as at all closely related to either *Stylophyllopsis* or to the multiseptate, richly dissepimental Triassic species usually placed in *Montlivaltia.*

Stylophyllopsis mucronata differs from the more typical species of the genus in a number of respects. Its short form, solid endothecal deposit, and small base of attachment suggest slow upward growth of the corallum in fairly deep water, free from strong currents and are therefore adaptive rather than progressive characters. But in the development of a septal columella and in the linear arrangement of the granulations over the most compact portions of the septa, which are features only well shown at maturity, we have signs of progressive change. In these characters *S. mucronata* approaches *Cyathophyllia*, which appears in the Middle Lias and resembles *Montlivaltia* except that it possesses a well-developed trabecular columella; but in the absence of more convincing evidence it is impossible to say whether or not *Cyathophyllia* was actually derived from *Stylophyllopsis*. The evidence is merely suggestive, but it is worth bearing in mind in any further investigations of these corals. Unfortunately the absence of well-defined ontogenetic stages and the present scarcity of exposures in coralliferous Liassic strata render the attempt to work out a natural classification of Liassic corals a difficult one.

There are, however, certain well-defined types of septal structure to be found, and by means of these it should be possible to divide the known species into a number of natural groups.

I have to thank Dr. W. D. Lang and Dr. F. L. Kitchin for permission to examine the Liassic corals in the British Museum (Natural History) and the Museum of Practical Geology respectively, and for the loan of specimens. My thanks are also due to Dr. A. E. Trueman, Mr. W. Tucher, and Mr. Linsdall Richardson for the loan of material from their private collections; to Professor J. W. Carr for permission to examine specimens in the Nottingham Museum, to Mr. J. W. Jackson for loan of material from the Manchester Museum, and finally to Professor H. H. Swinnerton, under whose supervision most of the work was done, for much valuable help, discussion, and criticism.

EXPLANATION OF FIGURES.

NO.

1.—*Stylophyllopsis rugosa.* Specimens showing repetition of Trochoid stage after rejuvenescence. (R.)

2.—*Stylophyllopsis rugosa.* Median longitudinal section showing discontinuous condition of inner septal edges.

3.—(*a*) Diagrammatic illustration of condition of inner septal edge. A.B. line of section normal to plane of septum.

(*b*) Appearance of inner septal edge of (*a*) in plane of section A.B.

4.—*Stylophyllopsis rugosa.* Transverse section showing a few isolated spines in the centre, dissepiments and tabulæ. (From a specimen in the Manchester Museum.)

5.—*Stylophyllopsis rugosa.* Portion of a transverse section as seen under low-power microscope. × 10 diam.

C = centres of calcification; L = lamellar fibrous deposit; R = radiating fibrous deposit; S = secondary deposit.

6.—*Stylophyllopsis mucronata.* Specimen showing growth constrictions (g.c.) and rejuvenescence (R.)

7.—*Stylophyllopsis mucronata.* A mature specimen showing the septal ornament.

8.—*Stylophyllopsis mucronata.* A very young corallite.

9.—*Stylophyllopsis mucronata.* Medial longitudinal section. The right half of the section is almost entirely in the plane of a septum.

NO.
10.—*Stylophyllopsis mucronata.* A specimen fractured down the middle to show macroscopic structure of the septa.
11.—*Stylophyllopsis mucronata.* Transverse section. The stippled area round the periphery indicates stereoplasm which there fills the interseptal spaces and buries the later cycles of septa.
12.—*Stylophyllopsis mucronata.* Part of a transverse section enlarged to show microstructure. × 10 diam. Lettering as for Fig. 5.
13.—*Stylophyllopsis victoriæ.* A specimen which has reached the Cylindroid stage. (*Mus. Pract. Geol.*, No. 31767.)
14.—*Stylophyllopsis victoriæ.*—Median longitudinal section.
15.—*Stylophyllopsis victoriæ.* Transverse section. (*Mus. Pract. Geol.*, No. 31764.)

Contact-Metamorphic Assemblages in the System $CaO–MgO–Al_2O_3–SiO_2$.

By C. E. Tilley.

IN previous papers[1] the assemblages characteristic of the systems lime-magnesia-silica, and magnesia-alumina-silica, in thermal metamorphism have been described, special reference being made to the range of mineralogical associates of rhombic pyroxene.

In the present note assemblages characteristic of the four component system, lime-magnesia-alumina-silica, are discussed. The composition of such assemblages composed of four phases can be represented in a solid figure, the tetrahedron. Such a figure when opened out is represented in the accompanying Figure 1, which reveals the essential three phase assemblages of the four three-component systems. The compositions of the various phases are represented by the points within the diagram. No important mineral of contact metamorphic origin is represented by a point within the solid figure, but it is to be noted that such minerals as diopside, grossular, and gehlenite, have a composition field within the tetrahedon if any solid solution is present, diopside with alumina, if augitic, grossular where small amounts of the almandine molecule are present, and gehlenite, which has always admixed the akermanite molecule. Artificial gehlenite and akermanite, as we know from the studies of Ferguson and Buddington, form a complete isomorphous series of solid solutions.

Examination of Figure 1 shows in a very clear manner how the assemblages of the systems can be divided into three types, occupying different areas. These are

(*a*) Free-silica hornfels assemblages
(*b*) Quartzless hornfels assemblages (carbonate free).
(*c*) Quartzless hornfels assemblages (carbonate bearing).

(*a*) *Free silica hornfels assemblages.*

The field of these opened out, is indicated by the ∴ dotted area of the figure, and is limited by the boundary lines wollastonite-grossular-anorthite-sillimanite-cordierite-enstatite-diopside-wollastonite.

---

[1] Geol. Mag., Vol. LX, 1923, pp. 101, 410.

If now we consider the four phase assemblages of the system, these are derived by joining the phases cordierite, diopside, enstatite, each with anorthite, and the phases grossular and diopside.

Five four phase assemblages are so obtained, and are those characteristic of the shale-limestone series of sediments, beginning with sillimanite-cordierite anorthite quartz, and ending with wollastonite-grossular diopside quartz.

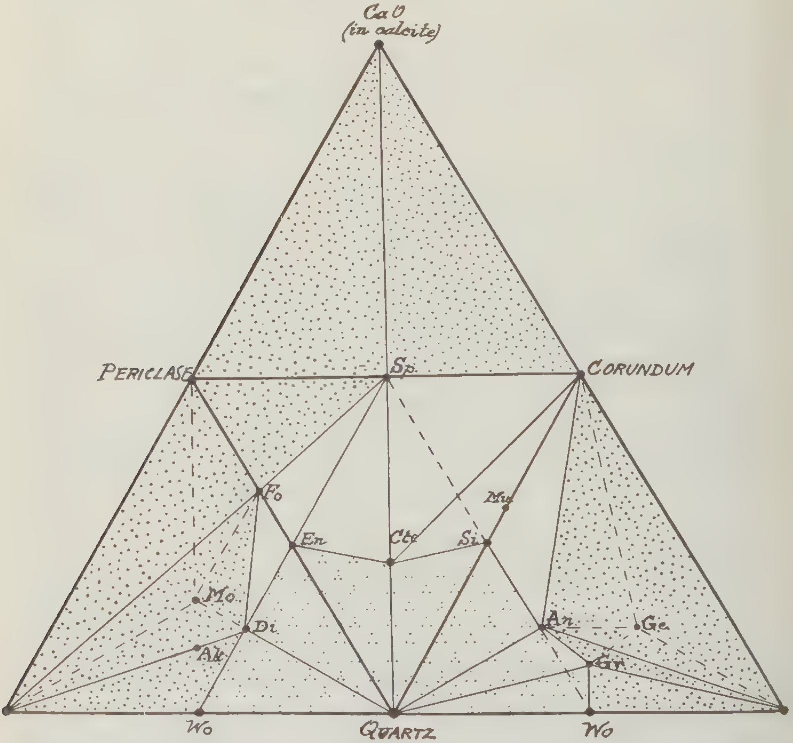

FIG. 1.—Wo=wollastonite, An=anorthite, Si=sillimanite, Cte=cordierite, En=enstatite, Di=diopside, Fo=forsterite, Sp=spinel, Gr=grossular, Ge=gehlenite, Mu=mullite, Mo=monticellite, Ak=akermanite.

b) *Quartzless hornfels assemblages* (*carbonate free*).

The field of these assemblages occupies the lower central region of the tetrahedon, and is bounded above by the surface corundum-anorthite-diopside-forsterite-spinel.

Considering the four phase assemblages, it is seen that these will be obtained by joining the phases spinel and forsterite, each with anorthite, and diopside and spinel.

Assemblages of this type are divisible into two groups, their fields being separated by the plane containing anorthite-enstatite-spinel. Above this plane we pass beyond the composition field of normal sediments, and enter the realm of basic (magnesian) igneous rocks, with which assemblages we are not now concerned.

Below the plane and towards alumina the assemblages are those of sediment composition. These are—

i. Cordierite enstatite spinel anorthite.
ii. Cordierite anorthite spinel.
iii. Cordierite corundum anorthite spinel.
iv. Cordierite sillimanite corundum anorthite.

Such assemblages have been described from sedimentary contact zones and are known from the contact zones of the Comrie diorite, Perthshire.

(*c*) *Quartzless hornfels assemblages* (*carbonate-bearing*).

Here are included the contact marbles, and the carbonate-bearing calc-silicate rocks.

In these assemblages all the minerals whose composition points are situate on the upper boundary surface of the field of the assemblages of the carbonate-free quartzless hornfelses, are stable in the presence of calcite.

The stability field of calcite is represented by the dotted area in Fig. 1. Neglecting for a moment the rare minerals, gehlenite and monticellite, the four-phase assemblages may be indicated by joining the phases grossular-spinel.

Grossular spinel assemblages are known in contact zones and have been described by Hutchings in the aureole of the Whin Sill; they are also recorded from the Monzoni contact zone.

We then obtain—

i. Grossular diopside spinel anorthite,

the field of which occupies the central area of the tetrahedron, and the remainder are—

ii. Wollastonite grossular diopside calcite.
iii. Grossular diopside spinel calcite.
iv. Grossular anorthite spinel calcite.
v. Diopside forsterite spinel calcite.
vi. Forsterite spinel periclase calcite.
vii. Spinel corundum anorthite calcite.

Gehlenite and Monticellite Assemblages.

Despite their comparatively simple mineralogical composition, both gehlenite and monticellite are quite rare products of contact metamorphism. Both minerals appear as phases in the dry melt systems.

Gehlenite.

In the melts so far investigated gehlenite occurs in equilibrium assemblage with anorthite, corundum, pseudowollastonite, and lime-olivine, according to the composition of the melt.

Natural gehlenite is never found pure but always contains a considerable admixture of the akermanite molecule, e.g. gehlenite of Monzoni shows 58 Ge, 28 Ak, of Tulare Co., California, 66 Ge, 28 Ak, of Velardeña, Mexico, 76 Ge, 17 Ak.

In the described occurrences, its mineral associates in addition to calcite are spinel and diopside (Monzoni) ; grossular, diopside (Tulare Co.) ; grossular, diopside, spurrite (Velardeña) ; diopside (Kaiserstuhl, Baden) ; spurrite (Riverside, California) ; idocrase (Mount Royal, Quebec). The composition of natural gehlenite in the tetrahedron is in the field, grossular-diopside-spinel-calcite, close to the extended field of grossular-diopside-calcite.

Gehlenite is not infrequently represented by pseudomorphs in grossular and fassaite, and these indeed may suggest not only the instability of gehlenite under the P.T. conditions prevailing in contact zones, but also its normal equivalents in thermal metamorphism. A grossular-diopside-calcite assemblage appears then as the normal representative of gehlenite in contact limestones.

Monticellite.

In the dry melt system monticellite appears in equilibrium with akermanite, forsterite, periclase, and lime olivine, according to the composition of the melt. Natural monticellite is known in association with calcite, spinel, pyroxene, and forsterite, in contact limestones (Vesuvius). At Riverside, California, the extraordinary association monticellite-xanthophyllite is recorded by Eakle.

The rarity of monticellite in contact aureoles suggests that it is unstable over the P.T. range prevailing in normal contact zones. The representative assemblage is diopside forsterite calcite which may be regarded as the lower temperature association.

As in the case of gehlenite, so here the tendency of monticellite to pass over into and be replaced pseudomorphously by fassaite is in itself suggestive of such instability.

Assemblages of Pyrometamorphic Rocks.

Assemblages of pyrometamorphic type are specially revealed in the ejected blocks or xenoliths of Vesuvius and the district of the Eifel and in the recently described xenoliths of the tholeiite intrusions of the island of Mull.

Here not only has a higher temperature prevailed, but also an interchange of material has occurred between magma and xenolith. Many of such assemblages are undoubtedly unstable.

The influence of higher temperatures is, however, indicated in the nature of the assemblages, and these in some respects approach more closely to the assemblages of the dry melt systems.

For example, the cordierite corundum pair is represented more frequently by sillimanite-spinel, and eventually mullite takes the place of sillimanite.

Instead of grossular we find wollastonite and anorthite as mineral associates, as recorded by Lacroix and Brouwer for xenoliths in volcanic rocks. Lastly diopside takes up in solid solution notable amounts of the enstatite molecule, giving enstatite diopside and enstatite augite, which are unusual in normal contact aureoles. All these modifications are revealed in the multi-phase assemblages of the pyrometamorphic rocks.

The Occurrence of Zinc in the Ballachulish Granodiorite.

By FREDERICK WALKER, Ph.D., F.R.S.E., Rockefeller Science Fellow, Geophysical Laboratory, Washington, D.C.

THE question of the zinc content of the Ballachulish granodiorite (GEOL. MAG., Dec., 1924, p. 554) has now been thoroughly investigated, Dr. E. G. Zies, of this laboratory, having very kindly interested himself in the matter.[1]

A small specimen of the granodiorite was first reduced to a powder, which showed none of the characteristic zinc lines in its arc spectrum, but when a chemical separation had been made, faint indications of zinc were obtained on spectrographic examination of the final precipitate, though the quantity was less than 0·01 per cent of the whole rock. Over 10 lb. of fresh granodiorite were then obtained from Kentallen quarries and reduced to a fine powder by quartering, but this material was found to contain not a trace of zinc either chemically or spectroscopically. Finally, through the kindness of Mr. W. H. Herdsman, some of the original powder analysed was procured and once more a preliminary spectrographic examination of the powder itself showed no signs of the presence of zinc. After a chemical separation, however, the very slight final precipitate showed undoubted zinc lines in the photograph of the arc spectrum, though here again the quantity of zinc was less than 0·01 per cent of the whole rock. Check experiments proved that as little as 0·2 mgm. metallic zinc (equivalent to slightly over 0·01 per cent ZnO in the 2 gm. granodiorite samples taken) could be accurately estimated and showed strong zinc lines in the arc spectrum. The above results are in complete accord with those obtained by Dr. E. B. Ludlam, of Edinburgh University, who found faint zinc lines in the spark spectrum of the analysed specimen after separation of the interfering constituents. The sporadic presence of very small quantities of zinc in the Ballachulish granodiorite may therefore be regarded as established.

Zinc has on several previous occasions been detected in igneous rocks and estimated, but the quantities have generally been much larger than in the Argyllshire rock (*U.S. Geol. Survey, Prof. Paper* 127, p. 23). It is hoped at some future date to examine other Scottish granodiorites for zinc, in particular those of the S. Uplands, in view of their distinct mineralization. Unfortunately the zinc-bearing material from Ballachulish proved insufficient for an adequate mineral separation. The zinc-bearing constituent must, therefore, remain temporarily unknown, though magnetite is suspected. No trace of any zinc-bearing mineral was observed microscopically.

---

[1] An account of the methods of determination employed, subject to appropriate modifications in view of the different material used, is given in the *Nat. Geog. Soc. Tech. Papers*, Katmai Series, No. 3, pp. 161–3, 172.

The Occurrence of Boulders in the Tertiary Formations of Ecuador, South America.

By George Sheppard, Ph.D., B.Sc., F.G.S.

ALONG certain of the coast sections in the province of Manabi, Ecuador, a series of large igneous boulders (of a coarse granitic type) occurs in situ among normal Tertiary sandstones. Tertiary sediments form the greater part of the "littoral" or coast belt of this country. One of the masses of rock referred to above had a weight, at least, of twenty tons—an exceptional size for an undoubted constituent member of a sandstone or a conglomerate.

Of great importance and interest is the question, "By what natural agencies have these large boulders been transported from their parent intrusion (unquestionably the Andes, nearly 200 miles away) to their present position in the Tertiaries of the coast belt?" The effects of glacial activity cannot be applied in this case as no evidences whatever of such phenomena have been observed in this part of South America. In connexion with the above interesting problem, the following geological information can be considered:—

(1) The Tertiary formations of southern Ecuador consist almost entirely of shallow marine, or estuarine deposits (of an areno-argillaceous nature) and include sandstones, shales, and occasional conglomerates.

(2) The majority of these deposits were most probably laid down in lagoon-like basins or estuaries which fringed the western slopes of the continent in Post-Cretaceous times.

(3) From certain lithological phases occurring in the Tertiary strata it is evident that periods of excessive rainfall characterized the climate of that time, a factor which caused the flooding of the rivers debouching into the above-mentioned lagoons.

There is reason to believe that the climatic conditions which prevailed in Tertiary times were similar to those which obtain at present in this area of the tropics. A theory relative to the transportation of the enormous blocks, therefore, can be tentatively suggested; in effect, one which admits the carrying power of slowly moving mud fans, or valley detrital accumulations which have in the past gravitated from the higher continental uplands to the lower levels of coastal deposition.

In the region of Ecuador now under consideration (situate within half a degree of the equator) the climate is of a semi-arid type, and whilst it is recognized that the rainy season occurs between the months of January and March there is, as a rule, no great precipitation of rainfall for a succession of three or four years. Then follows, however, a truly wet season of exceptional magnitude, and when this happens the dry quebradas, or gorge-like valleys, are at once converted into swiftly flowing torrents, new drainage systems are initiated and the superficial deposits of the land are denuded and distributed to a remarkable extent.

It must be remembered in this connexion that for nine or ten months of every year the surface rocks are subjected to the influences of intense solar heat (alternated by relative cooling during the night periods) with the result that these upper layers of the strata are desiccated or reduced to such an extent that they are easily distributed by the action of running water.

During periods of heavy rainfall the valley slopes (normally devoid of vegetation and hence lacking the binding medium of roots, etc.) constantly flake off in parallel blocks of saturated mud and sand and, in a very short time, these masses of slipped material gravitate to the level of the valley floor. Here they coalesce into a mud stream many feet in depth which slowly moves down the valley carrying all loose detritus before it. Should exceptionally large boulders become incorporated in such a mud flow, or should they even rest upon the relatively harder surface (caused by the rapid evaporation of the moisture during the day time) it will be readily appreciated that this method of transportation is not altogether beyond the bounds of possibility. Probably their rate of progression would never exceed a few feet per annum, but this in the course of geological time would be quite sufficient to account for a distance of 200 miles, especially when it is realized that (in the special case under consideration) the coast line is several thousand feet below the level of the continental uplands.

It has been noticed also, that where the lateral channels meet the main gorge, or where the latter approximates the sea-level, a pronounced fan of detrital material occurs. This suggests that shortly after the cessation of the rains the moving mud stream is gradually arrested in its progress on account of the rapid drying of the upper layers of the detritus, and it finally comes to rest in the form of a large fan or cone simulating a beach or a terrace.

The St. George Scientific Expedition.

By L. J. Chubb, B.Sc. (London), Geologist to the Expedition.

ALTHOUGH the full account of the Geological work carried out by the St. George Expedition to the Pacific must await the working out of the specimens collected, the following brief preliminary notes may be of interest.

The Expedition, which was organized by the Scientific Expeditionary Research Association, sailed from Dartmouth on

9th April, 1924, and after brief calls at Madeira and Trinidad, passed through the Panama Canal on 13th June. The succeeding five months were devoted to the investigation of a number of islands within a radius of about 600 miles of Balboa, which was used as a base. The following islands were visited: Isla del Rey, Isla Gorgona, Coiba Island, Cocos Island, Taboga Island, and the Galapagos Group.

On 15th November, after refitting at Balboa the St. George paid a third brief visit to Gorgona, and then sailed for the Marquesas Group, which was sighted on Christmas Day. About five weeks were spent in the Group, and, after calls at two of the atolls of the Tuamotu Archipelago, Tahiti was made on 16th February, 1925.

Up to the date of writing (18th March), the most interesting geological results have been obtained in Isla Gorgona, and the Galapagos and Marquesas Groups, and it is proposed to confine these notes to the observations made in these islands.

When the Andes are traced northwards from Equador to Colombia they are found to split into three chains, and north of Buenaventura a fourth range, the low coastal Cordilleras of the Chocos, appears. Isla Gorgona appears to be part of a southerly, mainly submarine prolongation of this range. The island, which is about 6 miles long and one and three-quarters wide, is situated in lat. 3° N., at a distance of 17 miles from the nearest point of the Colombian coast. Its greatest length runs approximately N.N.E. to S.S.W., and it consists of a high ridge whose flanks have been deeply eroded by a great number of small streams, which have formed a series of gorge-like valleys separated by sharp knife-edged spurs. The whole island is thickly covered with dense jungle, which makes progress extremely difficult.

A fairly complete topographical and geological survey was carried out. The highest peak reaches an elevation of about 1,200 feet above sea-level, but elsewhere the average height of the central ridge is about 800 feet. Owing to the deep weathering of the surface, rock exposures are rare, except along the coast, and the field relationships of the rocks are often obscure. The predominant type is an ophitic dolerite, which is pierced by picrite dykes. The southern end of the island is composed of a green ash, and the northern end of a pillow lava, the interstices between the pillows being filled by a green breccia probably derived from the ash. The occurrence of fossiliferous sedimentary rocks should prove of great interest. They include shales, conglomerates, and a conglomeratic and other limestones. The limestones are very fossiliferous, being composed in great part of foraminifera, while macroscopic fossils are also abundant, the genera represented suggesting a tertiary age. The examination of these fossils and of the rock fragments included in the conglomerates should go far towards solving the problems of the age and geological history of the island.

The Galapagos Archipelago, situated on the Equator and in 90° W. longitude, is well known to geologists owing to the classic labours of Charles Darwin. The islands visited by the Expedition were James, Indefatigable, Charles, Albemarle, and Narborough. Each of the islands appears to consist essentially of a single volcano, except Albemarle, which is composed of five volcanoes united by their lava flows and ash spreads, and probably Chatham (not visited) which appears to consist of two. This fact has often been lost sight of owing to the form of some of the main volcanoes being obscured by one of the following causes :—

(1) Considerable subaerial erosion, as at Charles Island.

(2) The development of many subsidiary cones on the flanks of the main volcano, as at James Island.

(3) The shattering of the main volcano by an explosive eruption, leaving a caldera in which many secondary zones of considerable size have been built up, as at Bindloe Island.

It is probable that the North-Western islands of the Group are younger than the South-Eastern, as their lavas are fresher; they have suffered less denudation and such volcanic activity as has been recorded in the Group was observed in the Northern and Western Islands, James, Albemarle, and Narborough. The extreme dryness of the climate in the North-Western part of the Group, however, may be sufficient to account for the slight degree of weathering and denudation in these islands.

The scattered and irregular arrangement of the islands, roughly along two series of parallel lines running respectively N.W.–S.E. and N.E.–S.W., suggests that they were formed in association with block-faulting of the Atlantic type, rather than with mountain-formation of the Pacific type, and it will be interesting to learn what light the examination of the rock specimens collected will throw on this problem.

Some of Darwin's most interesting observations were made in the neighbourhood of Tagus Cove, on the west side of Albemarle Island. He describes the cove as occupying part of the crater of a shattered tuff volcano, and he mentions another tuff crater, a mile further south, which is occupied by a salt lake in the centre of which a small crateriform islet arises. The Expedition was fortunate in being able to throw further light on the history of this most interesting district.

The two craters are situated on the extensive lava flats which surround Albemarle Island. The Tagus system consists of an outer crater, about a mile in diameter, the centre of which is occupied by a secondary crater containing a beautiful circular salt lake, which was apparently not noticed by Darwin, though it was observed by the recent Beebe expedition. The cove occupies a breach in the outer crater wall, but does not extend so far as this central lake, from which it is separated by a low knife-edged ridge, 60 or 70 feet high. Darwin's southern crater has also been breached and opened to the sea at some time in the past, but the opening has been closed by flows of lava from the great volcano to the east, which have passed round the eastern limb of the crescentic crater wall and again closed the entrance.

The history of the two crater systems appears to be as follows :—

(1) After the building up of the main volcanoes which form the mass of Albemarle Island, secondary eruptions of tuff formed the two outer craters of the Tagus and southern crater systems.

(2) After a period of quiescence renewed activity built up the inner craters and the vents became blocked.

(3) The volcanic energy, seeking an outlet, shattered the southern walls of the outer craters of both systems, forming Tagus Cove, and the inwardly converging strata which Darwin noticed lining its walls.

(4) Lava from secondary cones high up on the flanks of the main volcano to the east flowed round the bases of both crater systems and closed the breach in the wall of the southern crater.

The Marquesas Islands, situated in about 10° S. Lat. and 140° W. Long., are a group of high rugged islands most of which rise to a height of between 3,000 and 4,000 feet. They are intersected by deep gorges and crowned by precipitous serrated ridges, and are composed almost entirely of volcanic rocks. Lacroix states that the predominant types are basalts and phonolitic trachytes, but he has also seen a fragment of leptynite purporting to come from Nuka Hiva. No rock of this type was found by the Expedition. Small coral reefs are found in a few localities.

The islands visited by the Expedition were Nuka Hiva, Hiva Oa, Tahuata, and Fatu Hiva.

The almost complete absence of coral reefs from the Marquesas, which is in such striking contrast to the atolls of the not far distant Tuamotus, and to the barrier reefs of the Society Islands, has been commented on by many observers. A few small reefs occupying bays on the northern side of Tahuata were investigated. Dr. C. Crossland, Marine Biologist to the Expedition, finds that the number of genera of corals present is exceedingly restricted, proving that the very slight development of reefs in the group has an ecological rather than a geological significance.

Although the group follows in a general way the trend line of Oceania as determined by E. S. Dana and J. W. Gregory, the islands are not elongated in the same direction, and they can hardly be said to show the festoon arrangement characteristic of other groups further west. They show rather a scattered grouping similar to that of the Galapagos or the Azores, a fact which suggests that they have been associated with an Atlantic rather than with a Pacific type of movement.

The study of the topography of these islands reveals an interesting history of elevation and depression. A great part of the southern and western part of Hiva Oa is occupied by a peneplane, elevated to an altitude of 1,300 to 1,600 feet above sea-level, sloping gently from north to south and deeply dissected by the gorge-like river valleys. Monsieur Clavel, of the Service Topographique, tells me that a large part of Nuka Hiva is occupied by a similar peneplane at an altitude of about 2,500 feet, sloping gently towards the south or south-west. On this island, also, there are a few very small outliers of elevated limestone, which in hand specimens exactly resembles chalk. The evidence for elevation appears to be conclusive.

On the other hand, the mouth of every stream of any importance in all the islands is deeply embayed. At the heads of all the embayments are deltaic flats, extending half a mile to a mile from the beach, and there is little doubt that at one time the salt water arms extended as far as the heads of the deltas. The embayments have the appearance of drowned river valleys, and are probably due to the submergence of the land, either by a post-glacial rise of ocean level, as suggested by Daly, or else the subsidence of the islands, in accordance with the views of J. D. Dana and W. M. Davis.

Finally every island in the group, so far as could be observed, is surrounded by an elevated ledge, often capped with cemented beach conglomerate, at an altitude of about three feet above the present level of high spring tides, and about 6 or 8 feet above a new ledge that is now being formed in places.

The tectonic history of the group therefore appears to be as follows :—

(1) A stationary period which was long enough to allow peneplanation of large areas of Nuka Hiva and Hiva Oa, though high ridges still rose above the plain, was followed by—

(2) Elevation which considerably exceeded 2,500 feet in Nuka Hiva and 1,500 feet in Hiva Oa. Either while this was in progress, or during a subsequent stationary period, the streams deeply dissected the peneplanes, probably cutting down to sea-level.

(3) A post-glacial rise of sea-level, or more probably a subsidence of the land ensued. The river valleys were flooded to a distance of a mile or a mile and a half from the former coastline. The deltaic flats at the heads of the embayments were initiated.

(4) The latest phase has been an elevation of about 6 feet, or possibly a fall in sea-level of the same amount. The deltas are probably extending, and there is evidence that the bays are shallowing.

The future programme of the Expedition includes Rurutu, Rapa, and Easter Island. After its return in the summer the examination of the specimens will be commenced and it is hoped that publication of the full results will not be long delayed.

The geological work of the Expedition has been helped by grants from the Department of Scientific and Industrial Research, and by the gift of collecting material from the British Museum, to which all specimens will be presented.

REVIEWS.

The Trilobites of the Leptaena Limestone in Dalarne. By Elsa Warburg. Bull. of the Geol. Instit. of Upsala, vol. xvii, pp. i–viii, 1–446, pls. i–x, figs. 1–23.

MISS ELSA WARBURG must be congratulated most heartily upon the completion of this excellent Monograph, which will undoubtedly be welcomed by all workers on the Lower Palaeozoic rocks, and by none more warmly than by those in Great Britain and Ireland, where in the Keisley and Chair of Kildare Limestones a somewhat similar calcareous facies is found in the highest Ordovician rocks. The first section of the monograph deals with terminology, and by means of a fully labelled diagram the significance of the different terms used is clearly indicated, whilst notes in the text afford a valuable guide as to the relation and nature of those parts of Trilobites which may appear different in different forms. Then follows a section dealing with the present state of our knowledge regarding the systematic position of the Trilobites and their classification. Here the author obviously feels the difficulties shared by many palaeontologists at the present day when dealing with early groups of fossils, namely that they do not really agree with any existing forms ; and this is hardly surprising when it is remembered that in the case of the Trilobites we are in all probability dealing with a group of organisms evolving rapidly along several diverging lines from an ancestral stock ; the wisdom of the author is therefore to be commended in not forcing the issue, but in regarding them as constituting a sub-class of the Crustacea by themselves. As regards the question of classification, the same principle is involved, that of the doubtful plan of trying to force a relatively primitive group of organisms into a modern scheme ; and we agree cordially with the author " that among the several attempts made by different authors to construct a general classification of the Trilobita none can be said to be successful ". The attempts fail because, as she says, they are based upon characters of minor importance from a phylogenetic point of view ; but we may ask what are the characters that are important in this respect ? The author considers that much has yet to be done in the study of larval and transitional forms before this question can be answered, and we should like to add also, that more work in the field is necessary in order to decide the extent to which characters are affected by different physical conditions, and the nature and relationship of these in successive groups of strata. A very able and convincing critical survey is then given of the present state of our knowledge concerning the larval development of trilobites, the origin and course of the facial suture and points of structure connected with these ; here the work of Beecher, Walcott, Lindström, Matthew, Swinnerton, and others is shrewdly criticized. Like many palaeontologists before her, the author attacks Beecher's well-known classification, but her criticism is fresh and is based on the grounds that insufficient attention has been paid to the fact that several characters, which may seem to be primitive, are often due to secondary reduction, also, that some of the stages of evolution may be eliminated in the development of the individual, and others may simply be adaptations to similar conditions of life. She points out, too, that it is dangerous to draw conclusions from the larva of one group as to the phylogeny of another as has been done by Beecher. Swinnerton's revised classification, though based on Beecher's, is regarded as a decided improvement upon it, though not entirely satisfactory; for reasons are given to show that it is not necessary to regard the Proparia as a natural group in opposition to the Opisthoparia, the difference here being not in the development of the facial suture, but as to whether the genal or inter-genal spines became dominant, and the conclusion is reached that what the author terms "Opisthoparian conditions" evolved independently and at different times; hence, if it is wished for the sake of convenience to retain these two divisions, they must not be regarded as phylogenetically natural groups. Attention is directed in connexion with the development of the facial suture to the fact that it is always nearer the margin when the eyes are reduced, and thus the narrowness of the free cheek is connected with the reduction of the eyes.

The above remarks will serve to indicate the important nature of the subject in this section, which is well worth the careful attention of all interested in evolutional palaeontology. The main part of the work, as indicated by the title, is descriptive and is admirably done; it might well serve as a model for future work on the same lines; under each genus, where more than one species is described, the distinguishing characters of all the species dealt with are given, and each is then described in detail, special attention being directed to their affinities with other forms. Not the least valuable part of this work is the re-figuring and re-describing of the species of many older Swedish workers such as those of Angelin, Sjögren, and Linnarsson. The ambiguity that has existed with regard to some of these owing to the imperfections of the old figures is now removed. As might reasonably be expected a few new genera and several new species are described and figured. The last part of the Monograph dealing with the age of the Leptaena Limestone, as inferred from the Trilobites, is by no means the least important; for the age of this limestone has been in dispute owing to its peculiar lithology and faunal characters; it is now clear, however, that it is a true facies formation, and its age may be regarded as settled, for the author considers that the evidence tends to show that there are two Leptaena Limestones and that each of these represents "reef building", though not necessarily of coral reefs; the author brings forward reasons for the belief (1) that the Leptaena Limestone reefs were formed during two different periods interrupted by a time when no reef building took place, (2) that the older reefs (Lower Leptaena Limestone) are to be correlated with the upper part of the Chasmops beds, and perhaps with the lowest part of the Trinucleus Shales also, the reef building having, however, ceased before the Black Trinucleus Shales were deposited, (3) that the younger reefs (Upper Leptaena Limestone) are approximately of the same age as the Brachiopod Shales, the Klingkalk, and Étage F of the East Baltic area. The West Baltic Leptaena Limestone as well as the Keisley Limestone of England, the Kildare Limestone of Ireland, and Kiaer's Étage 5 of Norway appear to belong to the Upper Leptaena Limestone. A series of tables indicating the distribution of the different Trilobite species shows in a convincing manner the facts upon which these conclusions are based. The two limestones are clearly distinct faunistically, and the recognition of this fact is due primarily to the author, though it has also been urged by both Raymond and Isberg. It is clearly a fact of great importance, as it affects the reputed range of many fossils.

It only remains to add that the text-figures and plates are alike excellent, and maintain the high standard we have come to expect from Swedish publications.

G. L. E.

THE GEOLOGY OF NORTH LONDON. Explanation of one-inch Sheet 256 England. By C. E. N. BROMEHEAD, with contributions by H. G. DINES and J. PRINGLE. Mem. Geol. Surv. pp. xiii+63, 1 plate, 1 text-figure. 1925. Price 1*s*. 6*d*.

THIS, with its companion memoir "The Geology of South London", embodies the results of the recent survey of the area on the six-inch scale. Most of the district, which is here interpreted as extending as far north as Watford and Enfield, is now built over, and many of the exposures on which are based the facts given in the memoir are no longer available. The formations described include the Chalk (*Cor-anguinum* Zone), the Woolwich and Reading Beds, London Clay, Claygate Beds, and the various Pleistocene deposits, including the River Terraces.

A. G. B.

LA DÉTERMINATION DES PLAGIOCLASES DANS LES COUPES MINCES. By L. DUPARC and M. REINHARD. *Mém. Soc. Phys. Hist. Nat. Genève*, vol. xl, pp. 1–149, with 12 plates.

THIS useful memoir is an account of the methods employed for the determination in thin slices of the various plagioclase felspars, assumed free from potash; and it offers a practically complete presentation of the subject to the present time. After a general introduction the different methods of determination are treated under several heads: (1) the method of extinction-angles as developed by Fouqué and Michel Lévy, (2) the "theodolite" treatment of Fédorof and Nikitin, (3) Becke's conoscopic method, (4) birefringence, (5) refractive index.

While essentially a compilation and collation of the solutions proposed by various writers for this question, so important to the petrographer, the present work includes not a little which is new. In particular, Michel Lévy's well-known diagrams, first published in 1894, are redrawn from data furnished by Becke. The authors, however, give the preference to Fédorof's method, which makes possible not only the identification of the plagioclases but the complete study of the various types of twinning; they recognize, however, that for most petrographers the simple determination by the mean refractive index is likely to prevail. When a noteworthy proportion of orthoclase enters into the composition of the plagioclases, we have no longer to deal with a linear series of varieties, and clearly a single quantitative measurement will not suffice to determine the composition. The data for solving this larger problem are still to seek.

A. H.

THE GEOLOGY OF THE COUNTRY NEAR BRIGHTON AND WORTHING. By H. J. OSBORNE WHITE. Mem. Geol. Surv. Explanation of Sheets 318 and 333, pp. vi + 114, 14 text figures, 4 plates. 1924. Price 3*s*. 6*d*.

THIS agreeably written memoir deals with deposits ranging from the Wealden to the modern shingle bank at present travelling eastwards along the coast. The country has not been remapped, and the fossils recorded are in many cases taken from already published sources. From the Gault, however, sufficient specimens have been collected to enable a correlation with the classic Folkestone section to be made; the ammonites have been named as definitely as the totally inadequate number of names at present available will allow. As is becoming the usual practice of the Survey, the numbers under which these specimens are catalogued are given; so that should the significance of the names under which they are recorded ever change with the progress of research, the exact value of the record may easily be ascertained by re-examination of the specimen on which it was based. The author still retains Jukes-Browne's term Selbornian for the Gault and Upper Greensand, which, as Dr. Spath has more than once pointed out, is redundant and unnecessary.

In the Upper Chalk Mr. Brydone's division of the *Quadratus* zone is adopted, and a *Quadratus* zone (s.s.) and a *Pilula* zone recognized.

Taken in conjunction with Mr. Gaster's recent paper in the *Proc. Geol. Assoc.* on the Chalk of the Worthing District, this memoir should prove of great interest and use to the worker and collector in the region described.

A. G. B.

GEOLOGICAL SURVEY OF NYASALAND: Ann. Rep. for the Year 1924. By F. DIXEY, Government Geologist. pp. 1–8.

SEVERAL items of importance appear in this short Report, which is largely and properly concerned with the economic side of the subject, such as water supply, the coal borings on the Lower Shire and the discovery of bauxite (of an excellent quality) on the Mlanje Plateau. Clearly much good work is being done. The finding of the first recorded palaeoliths in the Protectorate and the discovery of dinosaurs near the north-western frontier are matters of general interest. Financial handicaps are inevitably responsible for much, but all concerned with the structure and history of Central Africa will hope that Dr. Dixey's Report on the Shire Rift Valley will shortly appear and prove to be the forerunner of others wherein pure geology can receive more attention than is possible in these annual summaries.

J. P.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

Friday, 3rd July, 1925.

A lecture was given on " The Geology of South Shropshire ", by Professor W. W. Watts, Sc.D., F.R.S., F.G.S.

The following papers were taken as read :—

" Unconformities in South Shropshire," by E. Sterling Cobbold, F.G.S. " Notes on the Comley Sandstone," by E. Sterling Cobbold, F.G.S. " Notes on the Shineton Shales," by O. M. B. Bulman, B.Sc., F.G.S., and C. J. Stubblefield, B.Sc., F.G.S. " Notes on the Valentian Series of Shropshire," by W. F. Whittard, B.Sc., F.G.S. " Notes on the Highest Silurian Rocks of the Long Mountain," by J. E. Austin, B.Sc. " Notes on the ' Old Red Sandstone ' of Shropshire," by W. Wickham King, F.G.S. " Notes on the Lowest Carboniferous Rocks of the Wrekin District," by Smith Bracewell, B.Sc.

" The Petrography of the Upper Kimmeridge Clay and Portland Sands of Dorset, Wiltshire, Oxfordshire, and Buckinghamshire," by E. Neaverson, D.Sc., F.G.S.

The Upper Kimmeridge Clay forms a discontinuous outcrop extending approximately south-westwards from Bucks to Dorset. The so-called Portland Sands of Dorset contain an Upper Kimmeridgian fauna, but certain sands in Bucks appear to be equivalent to the lower part of the Portland Stone series of Dorset. Of the heavy detrital minerals, garnet, magnetite, ilmenite, tourmaline, zircon, rutile, staurolite, and kyanite are consistently abundant, while spinel, anatase, apatite, corundum, andalusite, brookite, hypersthene, topaz, chlorite, chloritoid, epidote, glaucophane hornblende, muscovite, sphene, and zoisite are more sporadic in occurrence. Chert and other pebbles are abundant at certain horizons in Bucks and Oxon. Phosphatized fossils are characteristic of two horizons near Aylesbury and Swindon respectively, in each case marking a considerable non-sequence. The distribution of the pebbles and detrital minerals leads to the conclusion that the sediments of Dorset were derived from the rocks of the old Armorican *massif*, but that the detrital material in the Wilts, Oxon, and Bucks deposits had a northern (possibly Scottish) origin.

MINERALOGICAL SOCIETY.

16*th June*, 1925.

Dr. A. Hutchinson: The Use of the Stereographic Protractor for the Interpretation of Laue Crystal photographs. By a slight modification, the Stereographic Protractor previously designed by the author can be used for the interpretation of Laue photographs.

Dr. A. Hutchinson: The Use of Alignment Charts in Crystal Optics. The alignment charts in common use amongst engineers can be applied to the calculation of refractive indices measured on the total refractometer.

H. E. Buckley and W. S. Vernon: The Crystal-structures of the Sulphides of Mercury. The powder method of X-ray analysis showed that the precipitated black sulphide is cubic with the symmetry of the natural metacinnabarite and with an arrangement of atoms like that of zinc blende, $a=5{\cdot}85\text{Å}$; d (Hg–S)$=2{\cdot}54\text{Å}$. In cinnabar the arrangement of the Hg and S atoms is a rock salt one slightly compressed along the trigonal axis and with a slight readjustment of atoms parallel to the basal plane, $a=4{\cdot}16\text{Å}$, $c=9{\cdot}54\text{Å}$, $c/a=2{\cdot}291$. The type of movement in best agreement with the symmetry is $D_3 4$. In cubic mercuric sulphide each atom has four oppositely charged neighbours at a distance of 2·54Å, while in cinnabar two neighbouring atoms are situated at a distance of 2·54Å as in the cubic mercuric sulphide and two others at a distance of 2·91Å. These facts indicate an eccentricity of the mercury atom if the sulphur atoms are regarded as spherical. In cinnabar, in accordance with the circular polarization, sulphur atoms run down through the structure in trigonal spirals.

Dr. Edmondson Spencer: Albite and other Authigenic Minerals in Limestone from Bengal. The limestones of Cuddapah age near Raipura, Bengal, contain well-formed crystals of pure albite, apparently authigenic in origin. The crystals are tabular on the trachy-pinakoid and are lozenge-shaped. They are twinned on Carlsbad and albite laws similarly to those of the well-known Roc-toirné type, but of different habit. Accompanying the albite are phlogopite, tourmaline, and quartz crystals, all believed to be authigenic. Comparisons are instituted with similar occurrences of felspars in limestones from various European localities.

Dr. Robert Campbell and J. W. Lunn: Chlorophaeite in the Dolerites (Tholeiites) of Dalmahoy and Kaimes Hill, Edinburgh. The dolerites of Dalmahoy and Kaimes Hills are exceptionally rich (up to 15 per cent. or more) in chlorophaeite which occurs as a vesicle mineral, as veins, and as pseudomorphs after fayalite. The mineral has a refractive index 1·498, hardness 1·5, and density 1·81; it has no cleavage and is isotropic. It shows on exposure a striking colour change from bright olive-green to black, due to rapid oxidation. From its physical and chemical characters the mineral is regarded as of a colloidal nature.

Dr. L. J. Spencer: Tenth List of new Mineral Names; with an Index of Authors.

MANCHESTER GEOLOGICAL ASSOCIATION.

12th May, 1925.

The Rev. Father G. Waddington, S.J.: The Carboniferous Succession in the Stonyhurst District.

This district has for the past 25 years or more had the somewhat doubtful distinction of being the centre of a controversy concerning the rocks lying between the white limestone of Clitheroe and the Pendle-top Grit. These rocks were grouped together by Dr. Wheelton Hind and J. Allen Howe in 1901, under the name of the Pendleside Series. The district comprises the country lying between Clitheroe to the north, Whalley to the south, Pendle Hill to the east, and Longridge to the west. The series, originally described as occurring typically on the west flanks of Pendle Hill, is found almost in its completeness in the banks of the Hodder and of the Ribble respectively. The section on the Hodder occurs near Hodder Place, the preparatory school belonging to Stonyhurst College, and shows most of the lower portion of the so-called Pendleside Series. The Ribble section is found at Dinckley Ferry, and it can be demonstrated that this section is complementary to the section at Hodder Place, giving an exposure of the upper beds as far as the Pendle-top Grit. According to the author the Hodder section represents the true Yoredale Series of Wensleydale and the upper limestones of the Avon Gorge, Bristol, as described by Dr. A. Vaughan. The Dinckley section represents the Bowland Shales of Phillips, and contains the fossils characteristic of those shales wherever they occur.

OBITUARY.

F. W. Moon.

All those interested in the study of Egyptian geology will have heard with deep regret of the sudden death of Mr. F. W. Moon on 21st February, 1925. He was returning from an expedition to the Red Sea, where he had been examining the distribution of the diatomaceous deposits (originally discovered by him when examining the samples from the Egyptian Government petroleum bore at Abu Sha'ar), and died in the train between Benha and Cairo as the result of heart failure.

Frederick William Moon was born in Galway, Ireland, of Scotch parents, and was educated first at Queen's College, Galway, and later at the Royal University, Dublin, where he took his B.E. degree.

He subsequently went as a civil engineer to the North-Eastern Railway in York, where he remained until 1906. He then received an appointment as Oil-field Geologist with Sir Weetman Pearson's Company, working in this capacity till 1910. During this period he visited the north and south of Mexico and Mexico City. He was due to go on leave in 1910, and the troublous period in Mexico having then begun, he and the other geologists were unable to return.

At the beginning of 1911 he was engaged as head Oil-field Geologist by the Langhat Oil Company of Sumatra, going there via trans-Siberian Railway. During the time he was with this company he visited practically every part of the Dutch East Indies, including Atyeh, Djambi, and all parts of Borneo. Also Kelantan and Siam. He spent many months in Java, visited the island of Timor, and also the Burma oil-fields. He further widened his experience by going to Shanghai to see his chief, and then to Japan for a holiday.

Finally, before leaving for Egypt, he went to Australia, visiting New Guinea on the way.

In 1917 he was appointed under contract through Mr. Beeby Thompson to take part in the geological examination of those areas of Egypt which were included in the Petroleum Research plan of the Egyptian Government. For this purpose he was attached to the Geological Survey, and for the next eight years worked in association with the writer, Mr. T. G. Madgwick and Dr. H. Sadek. He was a part author of nearly all the Petroleum Research Bulletins issued from 1917 onwards, and owing to his neatness in manipulation and accuracy had as his special portion of the work the drawing of the field maps and sections which were subsequently issued with the bulletins. This period was a happy one both for Mr. Moon and his co-workers, the pleasant atmosphere being in no small measure contributed to by his friendly disposition and enthusiasm. Later he and Dr. Sadek continued the studies together in North Sinai, obtaining valuable results which have been recorded in a series of Petroleum Research Bulletins. Mr. Moon was due to leave the Egyptian Government service in 1925 under the arrangements made between the British and Egyptian Governments for the reduction of the foreign staff, but there was a hope that his services might still be retained, there being no one on the spot competent to take his place. Mr. Moon was also deeply interested in the microscopic study of rocks, and a plan was being elaborated with the writer for the photographing of some of the rock-slides contained in the Geological Survey collections. The description of St. John's Island, in valued collaboration with Mr. Campbell Smith and Dr. Spencer, was a first visible result of his interest in petrography. But his greatest interest was aroused by his discovery of the Diatomaceae in the Miocene of the Egyptian Oilfields region. He at once re-examined the series of Oilfield samples kept in the Geological Museum at Cairo, and found that they were of widespread distribution. Keenly anxious for the fullest information he was in continuous communication with Dr. Rendle and Messrs. Payne and Taylor at the time of his death. It was one of the pleasures of my own official life to have this enthusiastic author bringing me the latest letters he had received, or showing me many of the beautiful objects which, with the delicate sense of touch possessed by him, he had mounted with great skill and care.

The presence at the funeral of the chief representatives of the Egyptian scientific services and societies indicated in what high personal esteem he was held and the deep sympathy felt for Mrs. Moon in her sudden bereavement. His colleagues (especially those in the Department of Mines and in the Geological Museum at Cairo, with whom he was most brought in contact) deeply feel the loss of one who was both a valued colleague and a friend.

CORRESPONDENCE.

ZONES AND PHASES IN THE UPPER PART OF THE AVONIAN.

Sir,—Workers in the Carboniferous Limestone of the North of England are under a debt of gratitude to Mr. Hudson for the important paper on faunal horizons in the Lower Carboniferous of North-West Yorkshire, published in your issue of April (p. 181). It will greatly facilitate correlation with other areas and, in conjunction with Bisat's invaluable work on the goniatites, goes far towards settling the long-standing questions of the positions or position, in terms of the Yoredale sequence, of the Pendleside Limestone and the reef-limestones of the Craven knolls.

In comparison with accurate correlation it matters little what labels we give to the pigeon-holes of our systems of classification, and the following remarks, therefore, are intended in no way to detract from the value of Mr. Hudson's work.

He seems to be under a misapprehension as to the meaning given by Vaughan to the terms "standard" and "phasal", a misapprehension apparently due to the heading of a table in one of the brief papers[1] in which this worker compressed so many ideas.

---

[1] "Faunal Succession in the Lower Carboniferous (Avonian) of the British Isles," *Rep. Brit. Assoc. for 1909* (Winnipeg), 1910, table ii.

The table sets out phases in the Avonian with reference to the equivalent zones that are based on standard faunas, but the heading " Phasal Equivalents of Avonian " might be and, indeed, appears to have been, taken to imply that the " standard " zones, including Dγ, are phasal, which would be a contradiction in terms as used by Vaughan and myself. In reality the " phasal equivalents " in the table are the zaphrentid-phases and *Modiola*- and *Posidonomya*-phases in the columns to the right of the " standard " zones. That this was Vaughan's intention when making the table I have no doubt, for I frequently had the advantage of discussing " standard " and " phasal " deposits with him, both terms being originally his. " Standard " limestones yield an abundant and unrestricted coral and/or brachiopod fauna (locally either order may predominate), and are appreciably pure and bedded (i.e. devoid of reef-structures) ; the phasal deposits are distinguished therefrom by a predominance of certain fossils and by lithological peculiarities.

I was, therefore, following Vaughan strictly in using[1] Dγ as a purely zonal horizon immediately above D_2. I was discussing a sequence, the West Cumbrian, that was almost similar in facies to the Yoredales and included a sensibly exact reproduction of the Great or Main Limestone. In using Dγ Vaughan states, after the remark quoted by Mr. Hudson (p. 181), that it is typically expressed in the fauna of the Main Limestone of the Yoredales, and that D_3 connotes a phasal fauna.

My use of Dγ for the Cumbrian equivalents of the Main Limestone and higher Avonians, therefore, means no more than that they should be separated from D_2 below, and that, pending the report of the B.A. Committee now considering the question, we may go on using Dγ for them. Whether Dγ is the best symbol is another matter.

So much for the label. The question of phases, now raised, may perhaps be developed somewhat, as much has been learnt since the term was first used for Avonian sediments.

The selection of a particular kind of limestone and fauna as " standard " is arbitrary, and our dubbing other kinds " phases " in no way derogates from their importance or, if suitable, from their value in zoning. It may be, indeed, that the general deposits of the Avonian sea where freest from local influences, are the zaphrentid-phases, and that these should therefore be the " standards ". For in the southernmost outcrop in Pembrokeshire[2] the Tournaisian and the Visean, which as wholes there attain probably their most complete and deepest-water developments in this country, consist with the exception of little more than S_2 and D_1, of zaphrentid-phase deposits.

As to the use of " phases " in zoning, those that are characterized by an abundance of goniatites promise to afford a means of splitting up the highest beds of the Lower Carboniferous into narrower subdivisions than can be done on the basis of changes in the "standard" fauna. The value of goniatites was long ago recognized by Wheelton Hind, and in the hands of Bisat[1] they already point the way to order out of the chaotic and conflicting groupings of the strata near the border of the Lower and the Upper Carboniferous.

---

[1] In "A Sketch of the Geology of the Whitehaven District," *Proc. Geol. Assoc.*, vol. xxxvi, 1925, p. 51.

[2] "The County around Pembroke and Tenby," *Mem. Geol. Surv.*, 1921, p. 73.

Goniatite-phases and coral-and-brachiopod limestones are antithetical, and not related to one another in terms of depth of the area of deposition. Though the former are typical of the Upper Carboniferous and the latter of the Lower, the two facies tend to characterize different regions, and the goniatite-invasion has reached some places earlier than others.

It would appear that the contemporaneity of goniatite-phases with "standard" deposits and tendency to mutual exclusiveness of the two may necessitate two parallel sets of zones, the one based on "standard" faunas, the other on goniatites. This work, and the establishment of correspondences between the two sets, have been greatly advanced by Bisat, Hudson and others, and will weld into a harmonious whole the fruitful labours of Garwood, Hind, and Vaughan.

ERNEST DIXON.

SEASCALE, CUMBERLAND.

---

[1] The Carboniferous Goniatites of the North of England and their Zones," *Proc. Yorks. Geol. Soc.*, vol. xx, 1923–4, pp. 40–124.